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A Competency Framework for Participatory Modeling

Sondoss Elsawah[1,2] · Elena Bakhanova[3,5] · Raimo P. Hämäläinen[4] · Alexey Voinov[5]

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Abstract

Participatory modeling (PM) is a craft that is often learned by training 'on the job' and mastered through years of practice. There is little explicit knowledge available on identifying and documenting the skills needed to perform PM. In the modeling literature, existing attempts to identify relevant competencies have focused on the specific technical skills required for specific technical model development. The other skills required to organize and conduct the stakeholder process seem to be more vaguely and poorly defined in this context. The situation is complicated by PM being an essentially transdisciplinary craft, with no single discipline or skill set to borrow ideas and recommendations from. In this paper, we aim to set the foundation for both the practice and capacity-building efforts for PM by identifying the relevant core competencies. Our inquiry into this topic starts with reviewing and compiling literature on competencies in problem-solving research areas related to PM (e.g., systems thinking, facilitated model building, operations research, and so forth). We augment our inquiry with results from a PM practitioners' survey to learn how they perceive the importance of different competencies and how the scope of these competencies may vary across the various roles that participatory modellers play. As a result, we identified five core competency areas essential for PM: systems thinking, modeling, group facilitation, project management and leadership, and, more recently, designing and running virtual workshops and events.

Keywords Modeling with stakeholders · Systems thinking · Group facilitation · Online workshops design · Skill

"The ideal engineer is a composite … He is not a scientist, he is not a mathematician, he is not a sociologist or a writer; but he may use the knowledge and techniques of any or all of these disciplines in solving engineering problems."
N. W. Dougherty (1955).

✉ Sondoss Elsawah
s.elsawah@adfa.edu.au

Extended author information available on the last page of the article

1 Introduction

Participatory modeling (PM) is a problem-solving approach that capitalizes on bringing together concerned system stakeholders and leveraging modeling capabilities to support several purposes, including problem structuring (Franco 2008; Franco and Montibeller 2010), decision-making (Mustajoki et al. 2004; Bayley and French 2008; Falconi and Palmer 2017), deliberation and negotiation (Barnhart et al. 2018), transdisciplinary research (Smetschka and Gaube 2020), planning and public policy design (Zellner and Campbell 2020). There are various traditions of model-based systems analysis and decision support approaches that are related to PM. To name a few, these traditions and approaches include: Soft Systems Methodology (Checkland 1981), Strategic Options Development and Analysis (Ackermann et al. 2005), facilitated modeling (Franco and Montibeller 2010; Herrera et al. 2016), group model building (Vennix 1996; Andersen and Richardson 1997; Scott et al. 2006), companion modeling (Etienne 2013), collaborative modeling (Basco-Carrera et al. 2017), structured decision making (Gregory et al. 2012), and mediated modeling (Van den Belt 2004), etc. Essentially, these approaches share broadly the same goals and methodological content, so following Voinov and Bousquet (2010), we consider PM as an umbrella concept that includes all of the various approaches. Because of the broad theoretical and methodological basis on which PM can be grounded, there is no specific blueprint of what a PM may look like. Voinov and Bousquet provide a generic conceptualization of the PM process to encompass the following phases: identifying project goals, identifying and analyzing stakeholder needs, selecting a modeling approach, data collection, scenario analysis, and communication of results. PM has been applied in a wide range of domains, such as policy design in health systems (Freebairn et al. 2018), business (Rouwette et al. 2002), natural resource management and environmental conservation (Gray et al. 2018; Marttunen et al. 2015), disaster management (Hedelin et al. 2017; Mustajoki et al. 2007).

The growing complexity of the problems we try to solve and the increasing need for engaging the stakeholders and the broader public in managing these problems (Dlouhá and Pospíšilová, 2018), has brought growing attention to and interest in PM as an effective approach to produce usable and relevant knowledge, that can be used in decision and policy making. This is evident in the growing literature on the various aspects related to PM research and practice (Voinov 2020; Voinov et al. 2018) and group decision-making in general (Salo et al. 2021). However, while the benefits and importance of PM are increasingly recognized and advocated in several fields and domains, to date there has been little consideration of the competencies and skills required to effectively undertake PM.

In this paper, we use the term competency, after Shavelson's (2010, p. 44) synthesized definition. In Shavelson's words, a competency involves the following: "*(1) a physical or intellectual ability, skill or both; (2) a performance capacity to do as well as to know; (3) standardization of the conditions under which performance is observed; (4) some level or standard of performance as"adequate,""sufficient,""proper,""suitable" or"qualified"; and (5) improvement*".

Related competencies are often grouped into competency areas or competency domains (Sandwith 1993). The term 'competency framework' is used to describe how a set of competency domains relate to a particular position or role. A 'competency scope' indicates the desired level of competency that a person needs to exhibit to perform a particular role. The term competence indicates the overall collection of competencies or abilities that a person actually has. Competencies are measured against standards or a baseline to produce a competency profile.

PM remains to be a craft that is often learned by training 'on the job' and mastered through years of experience. There is little cross-field consolidated knowledge available on the evaluation of the skills needed to perform PM. Some computational modeling fields, say System Dynamics, have made attempts to identify and formalize the core modeling competencies required for effective model building (e.g., Schaffernicht and Groesser 2016). However, these attempts have focused on the technical aspects of building a computational model, and did not consider the holistic set of competencies required for the PM process. Whereas building a model is a key aspect in PM, which differentiates it from other participatory research and decision-making approaches, employing PM is not simply about building a computational model. The model does not even have to be computational; it may be sufficient to build a qualitative model of the system to meet the project goals. Designing, implementing, and managing a PM project is a complex intervention involving multiple actors, and several socio-technical processes (Hämäläinen and Lahtinen 2016), and necessitates particular skills. This brings into focus the effects of behavioral factors which are always present in modeling and group processes (Hämäläinen et al. 2013; Slotte and Hämäläinen 2015, 2015; Franco et al. 2021). One example is the assessment framework for facilitators presented by Azadegan and Kolfshoten (2014). Also, some of these competencies have been addressed before in the operations research literature, for a review see Ormerod (2014). Friend and Hickling (1987) provide an early discussion of skills needed in decision support processes. Yet, particularly in the PM context, we still do not have a clear understanding of the competencies needed to perform it effectively. The situation is complicated by PM being an essentially transdisciplinary craft, with no single discipline or skill set to borrow ideas and recommendations from. It also assumes a variety of modeling techniques, well beyond only, say System Dynamics (Voinov et al. 2018).

To start addressing this gap, this paper aims to set the foundation for identifying and understanding the practice of PM by addressing the fundamental research questions: *What are the core competency areas and skills required for the PM process? How does the scope of these competencies vary based on the roles that participants play in the PM process?*

Addressing these questions will contribute to our fundamental understanding of the skill requirements for effective PM practice. This understanding will strengthen the various aspects of PM education, research, and practice. From an educational perspective, this understanding should inform the development of relevant resources and activities to build these skills. The absence of a curriculum for PM is a barrier to building capacity and expertise in research and practice, and the field's progression to a mature profession. Identifying core competencies helps to identify opportunities for growth and development. Second, if we cannot define the fundamental skills needed to perform PM practices effectively and the developmental roadmap towards proficiency, then how will we know if participatory modelers are sufficiently qualified for running projects that deliver on all the aspirations (e.g. learning, decision-making, etc.) that PM promises?

To answer the above research questions, the paper pursues the following activities. First, we use a scoping review approach (Arksey and O'Malley 2005) for collecting and synthesizing PM-related competencies. This involves identifying relevant research topics, selecting literature, summarizing and reporting results. Second, we complement the review with data collected through an online survey of the PM community to identify and rank competencies according to the different roles participants perform in a project.

The paper is organized as follows. Section 2 provides an overview of PM principles and approaches. Part of this section is presenting the different roles of those engaged in a PM project. In Sect. 3, we present the set of core competencies. Section 4 reports on the survey method and results. We wrap up with conclusions and future outlook in Sect. 5.

2 Participatory Modeling

Participatory modeling (PM) refers to a broad range of scientific approaches, combining both participation and modeling approaches, to support research and problem solving for complex issues. PM is based on the premise that bringing stakeholders (i.e., scientists, end-users, interest groups) together through a process, designed around developing and using models for learning, sharing, organizing, and integrating knowledge about a complex problem, can lead to more useful outcomes than those achieved otherwise. Two core concepts constitute PM: *participation* and *modeling*.

In PM, participation and modeling are conceptually interlinked. One view is that both concepts are mechanisms for knowledge transfer. Another view is that modeling serves as a backbone process for supporting and facilitating participation, while participation enhances the quality and relevance of models. Participation is viewed as the fundamental principle and aspiration of active involvement of stakeholders and end-users in various phases of the research process. It is also closely connected to the learning process, when all stakeholders benefit from the experience. Several benefits and reasons rationalize the need and importance of participation. These can be distilled into four categories of reasons or functions (Jones et al. 2009; LaMere et al. 2020): normative, instrumental, substantive, and social learning.

1. The normative argument underscores the importance of participation as a pillar for democratic principles. Participation, as a goal in its own right, ensures that research design and decisions account for stakeholders' values and preferences.
2. The instrumental reasons underscore the importance of participation as a way to legitimize research implications for decision making and ensure that the research produces information that is useful for end-users. This has been also emphasized in the operational research literature (e.g. Rouwette 2011; Franco 2007) which

emphasizes the role of participatory process for the implementation of decisions as the stakeholders gain the trust and ownership over the results of modeling and discussion.
3. The substantive reasons link participation to the quality of obtained knowledge and information, and
4. Social learning is the expectation that through active participation and involvement in modeling stakeholders can get learning outcomes that cannot be realized otherwise. In fact, the learning extends beyond only social aspects, since stakeholders can also learn much about the technical details about the functioning system.

Modeling (as a research and problem-solving approach) goes beyond a particular field, it transcends scientific disciplines and application domains. In PM, a model is viewed as any simplified representation (or an artifact) of reality that is useful to serve as the basis for a discussion about the system it presents. Models take many forms, such as mapping methods, conceptual diagrams and flowcharts, mathematical formulas, algorithms, executable code, games, or any combination of these. Modeling brings the value of formalizing knowledge through the development of artifacts and objects that serve a particular purpose. Modeling purposes include (but are not limited to): clarifying arguments and values, engaging in data collection (calibration) and fact checking (validation), giving insights into possible courses for change, communicating about different futures. As noted in Sect. 1, there are different frameworks for describing the PM process in literature. These frameworks vary according to the underpinning theoretical and methodological stance, being reflected in the way the stages are framed to emphasize particular aspects (Voinov and Bousquet 2010).

There are also various roles involved in the PM process depending on the specific function to be performed. The extent that each role plays in the process depends on several project-specific factors, such as purpose, resources, and the process design. The following lists the main roles identified in the literature (Richardson and Andersen 1995; Van den Belt 2004; Vennix 1996; Hamalainen et al., 2020).

- The **team leader** role is focused on leading the project design, assignment, and recruitment for different roles, overseeing the project progress
- The **project manager** runs the process according to the set goals and format.
- The **facilitator** provides procedural assistance to support communication and group interactions. Part of this role is monitoring the group dynamics.
- The **modeler** (i.e., the model coach) is focused on model development, conducting the analysis, and reporting results.
- The **negotiator and mediator** roles are focused on helping the group to negotiate and reach an agreement successfully. Mediation is viewed as a class of facilitation specialized on conflict management processes.
- The **recorder** is focused on observing and documenting the participatory process as it unfolds, and administrating evaluation protocols, such as surveys and interviews.

(1)Richardson and Andersen (1995) claim that division of roles and allocation of a separate qualified professional for each role is desirable and can positively influence the process of facilitated modeling workshops. On the contrary, Huxham and Cropper (1994) suggest that the facilitator and modeler roles can be merged or, at least, the facilitator should have modeling skills. In practice, due to limited resources of the project, it is not rare that one professional performs several roles, yet, to our best knowledge, there are no studies that assess the impact of such role allocation or separation on the PM process.

3 Core PM Competency Areas

In this section, we present the core competency areas required for PM. We started our inquiry with a literature review in problem solving research areas which are related to one of the two pillars of PM: participation and modeling. The literature review aimed to identify the competencies and skills recognized in these areas, and their relevance to PM. Our review covered research areas, such as systems thinking (e.g. Midgley 2000), facilitated model building (e.g. Franco 2008), group decision making (e.g. Vennix et al. 1996), group model building (Rouwette et al. 2002), mixed methods traditions in operations research (e.g. Ackermann and Howick 2021), and problem structuring methodologies (e.g. Rosenhead 1996), strategy making and policy analysis (e.g. Ackermann and Eden 2011a, b), and communication (e.g. Tench and Moreno 2015). One challenge for synthesizing these competencies is the different framing (i.e., descriptions, levels of aggregation and specification) by which competencies are articulated across the literature. The authors negotiated and reconciled them throughout the iterative process of writing the paper, as well as while learning from a survey of PM practitioners that was conducted. Differences in framing the competencies are an inevitable challenge given the complexity and diversity of PM practices and the various competency frameworks that PM could draw upon. Streamlining differences and overlaps among these competencies is outside the scope of this paper and may not be even a feasible or a useful endeavor given that any attempt to synthesize this knowledge should be guided by the specific purpose for identifying these competencies largely influenced by the specific goals of particular projects. Our main purpose is to provide a core set of useful and meaningful PM competencies rather than claim a comprehensive framework.

The process of summarizing and synthesizing papers has resulted in identifying five competency areas or categories that define the needed capabilities for taking part in PM (Fig. 1). This core set serves as a guide to identify gaps in skills and abilities, and opportunities to address these to support the developmental growth of PM practitioners. Next, we present the five core competency areas, and refer to the literature where they have been identified and discussed. Two noteworthy points we would like to emphasize. First, while certain competencies such as modeling skills can be addressed by individual members of the PM team the entire process is a team effort and it is necessary to also consider the competencies as a group skill. Second, these competency areas have naturally overlapping elements, and therefore areas should not be considered as exclusive but as a holistic and interdependent set.

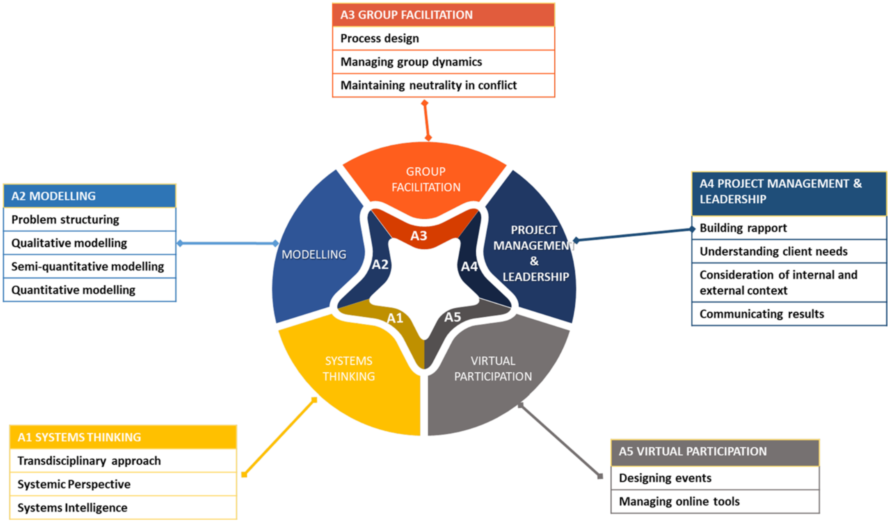

Fig. 1 Core competency areas for participatory modeling

Yet, identifying these areas and sub-categories is seen to be of help in clarifying the competence requirements.

3.1 Competency Area #1: Systems Thinking

The field of systems thinking is broadly defined as a transdisciplinary framework (i.e. concepts, methodologies, tools) which brings together scientific fields (e.g. decision science, engineering, computer science) to help solve complex and wicked problems. Unlike multi-disciplinary research (characterized with ad-hoc integration of knowledge geared towards solving a particular problem) or interdisciplinary research (characterized with blending knowledge from disciplines to generate new nexus methods while individual disciplines remain sovereign), transdisciplinary research efforts go beyond the scopes of specific disciplines and are characterized with systematic integration of knowledge to produce new knowledge bases (Lawrence 2010; Klein 2010, 2018) closely connected with stakeholder engagement and the knowledge that they can offer. Bosch et al. (2007) argue that systems thinking should be 'absorbed' into scientific problem solving approaches, the same way that statistics is integrated into scientific research. We expect the systems thinking competency area to cover the three interrelated competencies: transdisciplinary approach, approaching problems from a systemic perspective, and systems intelligence (Hämäläinen and Saarinen 2004). Next, we present an overview of these competencies and highlight the relevant literature.

Transdisciplinary approach is a form of inquiry that aims to transcend the scope of disciplines by systematically creating and integrating knowledge into a new knowledge base, going beyond the approaches of individual disciplines (Klein 2010). Some efforts have been targeted towards conceptualizing the competency to undertake transdisciplinary approaches. For example, Nash et al. (2003) identified the attitudes (e.g. valuing collaboration), knowledge (e.g. good understanding of research ethics), and skills (e.g. critical thinking skills) essential for scientists who carry out transdisciplinary research. In another effort, Augsburg (2014) expanded and shifted the discourse to view transdisciplinarity as an individual identity, and posed the question about what makes this identity. Augsburg (2014) identified a list of factors that contribute to transdisciplinary individuals, including: undertaking creative inquiries and respect of cultural relativism and diversity, being intellectual risk takers, and courage to abandon the comfort of one's own perspectives and discipline. In more recent work, Di Giulio and Defila (2017) identified two groups of transdisciplinary competencies:

1. competencies aiming to promote effective exchange and interaction between worldviews in a transdisciplinary process. These include familiarity with one's own discipline, its achievements, as well as boundaries and limitations; ability to articulate and reflect on one's perspective relative to others; and the ability to genuinely accept other disciplines' ontology and epistemology. There are several challenges that make it difficult to appreciate other disciplines' perspectives and be open to cross paradigms in order to participate in a genuinely transdisciplinary effort. For example, in the operations research field, Kotiadis and Mingers (2006) identified cultural (e.g. values around particular data and method types), cognitive (e.g. personality types) and practical challenges (e.g. time and effort) as obstacles. Glynn et al. (2017) focused on biases, beliefs, heuristics and values that can dominate in the decision making process and have to be properly acknowledged and treated.
2. professional competencies aiming to design and facilitate transdisciplinary processes. These include knowledge of the general challenges encountered during knowledge construction and integration processes as well as those specific to the problem and project on hand; ability to identify methods and practices to mitigate and address these challenges; and ability to 'translate' information about the process and its products in an effective way for multiple audiences.

Solving complex problems requires a *systemic perspective* that is focused on the interdependent drivers and factors that drive the problem behavior (Funke et al. 2018). This involves the ability to identify different perspectives, considering the wholes and parts, recognizing systems and boundaries, identifying and characterizing relationships, including feedback interactions, identifying and using intervention points to produce effects.

The literature on defining systems thinking skills started with broadly articulating the relevant types of thinking and mindsets. Richmond (2000), a pioneer in teaching system thinking, articulated seven broad areas that are essential for building system thinking: dynamic thinking, closed-loop thinking, generic thinking, structural thinking, scientific thinking, and operational thinking. In his classic book, "The Fifth Discipline", Senge (1990) defined four levels of thinking about problems: event (i.e., immediate symptoms), pattern (i.e., trends in behavior), structure (i.e., causal influences and drivers), and mental models. Senge argued that systems thinking involves the ability to recognize the four levels operating simultaneously on the problem.

Stave and Hopper (2007) developed a taxonomy for assessing systems thinking based on the review of literature and interviews with experts. The taxonomy includes seven skills organized into three levels: basic, intermediate, and advanced. Basic systems thinking skills include the ability to recognize interconnections, identify feedback, and understand dynamic behavior. Intermediate skills include the ability to differentiate types of variables and use conceptual models. Advanced skills include the ability to create simulation models and using models for testing policies. Plate and Monroe (2014) revised and extended the taxonomy to include an explicit description of each skill at four literacy levels: *below basic, basic, moderate, and advanced*. The revised taxonomy deviates from Stave and Hopper (2007) in two key points. First, the ability to understand systems at different scales is added as a key skill. Second, the development of quantitative models is dropped, and instead, the aspect related to this skill is added to the advanced level of each skill. Arnold and Wade (2017) drew on previous literature and proposed a broader framework, which organizes systems thinking skills into four categories: (1) mindset-related skills about how to approach systemic problems, such as the ability to explore multiple perspectives; (2) content-related skills about defining systems, such as the ability to draw boundaries; (3) structure-related skills about how to organize information about the elements and relationships of the system, such as the ability to identify feedbacks, and (4) behavior-related skills, such as the ability to understand system behavior.

Another line of efforts on characterizing systems thinking competencies building on the work of Senge (1990) is the concept of systems intelligence (SI) (Hämäläinen and Saarinen 2004). It refers to intelligent behavior in the context of complex systems involving interaction and feedback. In problem solving a person with systems intelligence sees the overall system and perceives herself as being a part of the systemic socio-emotional whole of problem solving and understands the influence of the whole on herself and her influence on the whole. The focus is on intelligent action and engagement rather than only describing the system from outside. The basic idea in including SI as a competence is that in PM the entire process also creates a social system which needs to be understood and managed as it has an essential impact on the behavior of the participants and the group dynamics. SI emphasizes the need to have a holistic approach where even emotional and cultural factors are considered. Naturally SI could also be considered to be a facilitation competence but we decided to place it as a systems thinking competence to emphasize the fact that when working with people a technical systems perspective is not enough. As noted earlier the competence areas do overlap. The eight factors of SI (Törmänen et al. 2016) are systemic perception, attunement, positive attitude, spirited discovery, reflection, wise action, positive engagement and effective responsiveness. These factors emphasize the importance of using systems thinking together with people skills and reflection in people engagement and group problem solving (Hämäläinen et al. 2014). SI is also an organizational competence (Törmänen et al. 2022). The PM team including all stakeholders creates an organization, which would benefit from improved SI as PM is a team effort. Kenny et al. (2022) describe how SI is also directly related to transdisciplinarity and the above mentioned four functions suggested by LaMere et al. (2020). The eight factors of SI are also suggested to represent the essential core competencies for successful engagement of next generation engineering professionals in complex systemic settings (Hämäläinen et al. 2018). The SI Test (http://salserver.org.aalto.fi/sitest/en/) provides people a means to evaluate and improve their SI.

3.2 Competency Area #2: Modeling

While it is hard to find competencies per se discussed in the context of modeling, there is ample literature on the good practice of modeling in various application domains. For example, a review of various requirements for the modeling process has been provided by Jakeman et al. (2006). The review stresses the importance of being aware of the purpose of modeling and making sure that modelers know the limitations, uncertainties, omissions, and subjective choices in models.

There are various conceptualizations of the modeling process which are often grounded in a particular problem domain and/or modeling methodology. Yet, there are common themes across these conceptualizations, which start with problem structuring and formulation and, go through several iterative cycles of model development (system conceptualization, formalization, computation) and analysis (sensitivity analysis, calibration, verification, and validation), and end with a product, the model that is handed over to the end-user.

Each of these steps of model development and testing requires certain competencies, which are expected to have been learned when preparing for a modeling career, or already on the job when building models. Naturally, it is imperative that modelers know what they are doing when modeling. Yet, there are a few challenges for identifying, conceptualizing and testing these skills.

First, some of these skills and supporting knowledge areas are dispersed among various problem solving approaches and application domains. For example, the body of knowledge on problem structuring and soft operations research (e.g. Soft Systems Methodology (Checkland 1981); SODA, Ackermann et al. 2005) provides extensive methodological contribution as well as practical lessons and insights on conducting problem structuring activities in facilitated settings. These methodologies could be used as a frontend process for the model development to bring in different perspectives in a structured way as a basis for identifying key issues and assumptions (e.g. Eden 1994; Howick et al. 2008). It also allows for defining scenarios of interest and performance indicators to be evaluated by the model (e.g. Elsawah 2010).

Moreover, as mentioned above, PM does not necessarily have to end in a quantitative computational model. In some cases a qualitative, conceptual model of some form can be sufficient, making some of the modeling skills mentioned above potentially redundant, though still certainly useful.

Second, the literature does not yet provide easy ways of testing modeling skills. It can well be that the modeler is familiar with only one method and not able to approach the problem with another more appropriate method. The risk of hammer and nail syndrome (Prell et al. 2007; Voinov et al. 2018) is often a real one. In practice, there is often a need to mix different modeling approaches. This has been recognized early (see e.g. Munro and Mingers 2002 and Ackerman and Howick 2021), but to what extent this need is taken into account in the planning of PM projects is not clear. In PM the modeling competence should be considered as a team competence so that within the modeling team there need to be people with competencies in different modeling techniques and analysis approaches. Alternatively, we may require more flexibility in outsourcing certain elements of the modeling process. We do not necessarily have to have all the skills for all sorts of modeling in-house. However, we do need to be prepared to recognize that there are better and more suitable methods available for the particular problem at stake and be ready either to acquire the additional skills by learning them all or by subcontracting to other parties.

Also, the way a model is used by different people can have an impact on the outcome. So, another aspect of the modeling competence is the ability to see the risks and mitigation possibilities of cognitive and behavioral biases related to modeling and knowledge elicitation (Hämäläinen et al. 2013; Slotte and Hämäläinen 2015, 2015; Lahtinen et al. 2017). So far, this practice deliberately leaves out the user and stakeholder interface (McIntosh et al. 2011). On the other hand, PM focuses on the modeling process rather than the model itself. In this case, all the stages of the process become less clearly delineated and may require multiple iterations as stakeholders may require. There also should be flexibility in cutting short the modeling process and delivering a qualitative model (as long as that is sufficient for the project goals), instead of insisting on concluding the full modeling process as it should be staged in full-fledged computational modeling (De Gooyert et al 2019). For example, the definition of project goals becomes one of the stages of the modeling process, which is revisited as many times as needed with active interaction between scientists and stakeholders. Based on some preliminary definitions of project goals, we may decide to invite additional stakeholders to the process, who, in turn, may require a redefinition of the model goals. The process becomes much less structured and assumes new competencies from the modelers, which would go beyond the scientific process of system analysis, formalization, equation solving, programming, and model testing. Now we may also need strong communication skills to deal with multiple stakeholders' needs and potentially conflicting priorities.

Modeling helps in clarifying values, vested interests, intentions, and actions, while most likely changing them at the same time. Modelers have to be prepared to act as equally engaged stakeholders and participate in a process of social learning (Tàbara and Chabay 2013) and co-design of knowledge (Glaser 2012). This will require additional skills, such as critical self-control feedback. Similarly, in the analysis of the model results, stakeholders are engaged to ensure that their expectations are met, and the results can be used in a trans-disciplinary framework (Seidl et al. 2013). While in most cases of traditional modeling, the scientists and modelers are assumed to be 'objective' and 'value-neutral' (Voinov and Gaddis 2017), participatory modeling leads to a new role of modelers in the process, when they have to adapt to the needs and skills of other stakeholders involved.

Voinov et al. (2014) expand the traditional modeling practices, coming up with "Ten 'commandments' for a socio-environmental modeling agenda" which deal with values and biases inherent in any PM process. The modelers are expected to learn to acknowledge implicit decisions and assumptions in modeling, learn to document and communicate them, and reject the position that models are always objective and value-neutral. A larger emphasis is placed on model transparency, explanation of how scientific facts can shape values, which in turn are fluid and can change when new knowledge becomes available. The modeling process itself should be treated as evolving and adapting to accommodate new knowledge and data, which may not have a final solution.

Of course, the best practices of rigorous model characterization and testing should be still followed (Bennett et al. 2013), which means that the associated competencies should be present. However, this remains a necessary, but not a sufficient condition of successful modeling, which still has to deal with all types of uncertainties as an inherent part of all complex systems.

PM assumes a wide arsenal of tools and methods (Voinov et al. 2018), including qualitative, semi-quantitative, and quantitative approaches, which all may require additional skills and competencies. Most importantly, we need to be open to alternative modeling approaches and flexible to engage additional expertise or outsource some modeling if needed.

3.3 Competency Area #3: Group Facilitation

Group facilitation implies a broad set of skills, some of which are generic and applicable to any group communication, while others could be specific to a particular methodology that is used (for example, the workshops that include model development or co-design of a product). There is a range of frameworks describing the core skills and competencies of a facilitator (e.g., Kolb et al. 2008; McFadzean 2002; Schuman 2005). The frameworks vary in the depth of details and approach for structuring the competencies. One of the most well-known frameworks developed by Schuman (2005) and used by the International Association of Facilitators (IAF) presents the competencies of the facilitator following the main steps of the facilitation process: developing relationships with a client before the workshop, planning the process of the workshop, sustaining the involvement of the participants during the workshop, guiding a group to some conclusions and so forth. A similar approach was applied in the framework by McFadzean (2002). Another perspective of structuring facilitation skills within a framework is based on the different fields from which those skills originate: technical, communication, personal, and others (De Vreede et al. 2002; Nelson and McFadzean 1998). Finally, there are several frameworks that combine elements from other frameworks or do not include any grouping (Clawson and Bostrom 1996; Kolb et al. 2008). No matter how different approaches structure the sets of skills within a framework, there is a significant intersection between all the above-mentioned frameworks.

Most of the facilitation competency frameworks include an ‘interpersonal communication’ skill set that contains an ability to actively listen to the group, summarize ideas, ask guiding questions, express yourself clearly in verbal and non-verbal forms and others (De Vreede et al. 2002; Kolb et al. 2008; Schuman 2005; Stewart

2006 and others). Additionally, many of the authors mention the need for a facilitator to have management skills, more particularly, such as understanding the context of the problem and business environment, building productive relationships with clients, understanding their needs, delivering the output of the workshop to clients in an effective way and so forth (McFadzean 2002; Nelson and McFadzean 1998; Schuman 2005). Some of the researchers also emphasized the ability of a facilitator to choose and use appropriate technologies to facilitate the process, for example, those that are associated with a visual aid (De Vreede et al. 2002; Kolb et al. 2008). The framework of Schuman (2005) also includes a subset of skills that lead to the long-term professional development of a facilitator, such as expanding the knowledge about facilitation methods, maintaining the reputation, and others. These skills perfectly fit the overall objectives of the International Association of Facilitators (IAF). Finally, the category of skills that seems to be the hardest to define and measure precisely is associated with personal characteristics of a facilitator and her attitudes, for example, friendliness, sense of humor, tact, self-confidence, and others (Kolb et al. 2008; Nelson and McFadzean 1998; Stewart 2006). Besides the process skills, competence in the design of the collaboration workshops is important (Kolfschoten et al. 2007).

The stage of stakeholder selection and invitation, which is considered as one of the crucial elements of the PM process, can be seen as an example of some delicate facilitation, where the facilitator should not dominate with their preferences, but instead should allow all parties involved to have a say and incorporate the opinions of newly engaged stakeholders in a dynamic process of engaging additional stakeholders as needed. The art of facilitation in this case is similar to other stages: the process needs to be managed, but not dominated or steered (Korfmacher 2001; Voinov and Gaddis 2008).

Apart from the generic frameworks, there is some less structured research that focuses on describing facilitation skills needed for strategy workshops (e.g. Ackerman et al. 2005) and group modeling workshops (Franco and Montibeller 2010; Van den Belt 2004; Vennix 1996). Ackermann and Eden (2011a, b) discuss the facilitation role and skills, including guiding and keeping the group on track. Franco and Montibeller (2010) mention such facilitation skills as active listening, chart-writing, managing group dynamics and power shifts, and reaching closure (Ackermann 1996; Andersen and Richardson 1997; Clawson and Bostrom 1996; Franco and Montibeller 2010). Managing group dynamics also implies consideration of positive and negative emotions of the participants and their impact on behavior. Martinovski (2021) elaborates on the influence of emotions on cognition, decision-making, and negotiation process. Hence, the facilitator should be able to deal with emotions of the participants in a productive way as well. Vennix (1996) discusses the facilitator's competencies in the context of group model building and divides them into two categories: attitudes and skills. Attitudes include integrity, authenticity, neutrality, and being helpful (Rouwette et al. 2002; Vennix 1996; Huxham and Cropper 1994). Among essential skills we find such as knowledge about modeling methods, communication and conflict management skills as well as process structuring skills. Van den Belt (2004) repeats most of the facilitator's competencies described by Vennix (1996) but in the context of mediated modeling as a particular approach. Slotte and

Hämäläinen (2015) (2015 suggest that Decision Structuring Dialogue is an essential skill in engaging stakeholders in the problem structuring phase.

3.4 Competency Area #4: Project Management and Leadership

Project management is an issue in varied contexts and organizational settings which can range from industrial and business to public services as well as to innovation and policy development. The paper by Do Vale et al. (2018) lists project management competency frameworks developed by three professional organizations (Association for Project Management, International Project Management Association, and Project Management Competency Development). The proposed competency model includes four groups of competencies: (1) behavioral (social skills of a project manager), (2) technical/specific (specific competencies based on the activities that a project manager performs), (3) management (ability to apply tools, techniques to run the project), (4) contextual (specific competencies based on field or industry where a project manager works). The competency framework of the Association of Project Management includes a more detailed list of skills such as team and conflict management, requirements management and change control, stakeholder and communication management (APM Competence Framework 2015).

Within communication management competencies there is also a large component associated with the social aspect of activities. Sustaining long-term relationships with key stakeholders, rapport building, and building mutual trust are among the core competencies of a communication manager (Flynn 2014; Jeffrey and Brunton 2011; Spencer-Oatey and Stadler 2009). These competencies seem to be of high relevance to the PM context as well. The success of the PM exercise is very much dependent on the inputs from stakeholders; therefore, maintenance of long-term stakeholder engagement is crucial. Additionally, knowledge about the organization, business, industry and constant monitoring of the external environment for understanding the changes are part of management competencies as well (Jeffrey and Brunton 2011; Tench and Moreno 2015).

Leadership is one of the personal qualities that is mentioned in the literature on project and communications management competencies (APM Competence Framework 2015; Flynn 2014). Hämäläinen et al. (2020) introduce the term leadership into the PM context and discuss the difference between management and leadership in PM. They also shortly characterize the key leadership competence in PM such as ‘ability to identify the risks and impacts of behavioral phenomena in modeling and stakeholder engagement’, ‘understand the big picture’, ‘know the stakeholders and empower them’ (Hämäläinen et al. 2020, p. 7).

The question of who decides about the participants and the stakeholders is an important one as the composition of the group is likely to determine the context in which the analysis is carried out. This will also be reflected in the learning insights which the representatives of the stakeholder groups will take back to their constituencies. The size and balanced composition of the group is critical for success (Voinov et al. 2016a, b). In some cases the PM project leadership is given the authority to select who is participating. This introduces another challenging competence requirement for the leadership.

3.5 Competency Area #5: Virtual Participation

Following the development of ICT technologies and the influence of social media on public opinion, online and virtual communication tools have experienced a steady increase in interest from facilitators and communication professionals (e.g., Kersten and Lai (2007) provide an early review of the use of e-negotiation systems). Voinov et al. (2016a, b) elaborate on the use of social media platforms and their potential for PM processes. Operational research literature also mentions the use of virtual tools for group decision support (e.g., Group Explorer software that mimics SODA approach) (Kilgour and Eden 2021). Interest in virtual formats has boomed even more in recent times when face-to-face meetings became problematic to organize because of COVID19 restrictions. In a recent paper, Wilkerson et al. (2020) reflect on adjusting standard group model building procedures to online format with the use of online communication platform Zoom and Miro software as a tool for visual aid. The authors suggest a set of technical and facilitation considerations that could help to run online modeling workshops smoother. For example, they mention such aspects as paying more attention to the preparatory stage of the workshop and having a detailed script; finding a balance between allowing the participants to interact with the model by themselves and guiding them through the model; paying more attention to building rapport and constantly checking whether everyone is on track, since it is significantly harder to sustain attention in an online format (Wilkerson et al. 2020). Another novelty associated with online PM workshops is the use of online artificial intelligence (AI)-assisted discussion forums such as the Discussoo platform (Anjum et al. 2021). In this case, almost no special skills are needed to translate a discussion on a complex topic into some conceptual models because the promise is that AI algorithms embedded into the platform can create the mental map automatically and in real-time. It may still take some time to develop appropriate algorithms and allow for the AI learning process before really useful conceptual models will be generated on the fly. This makes it even more important to constantly check the validity of the AI produced mental maps and find appropriate ways to embed such automated approaches into the overall facilitation process.

If one looks broader, competencies associated with running online meetings lie within facilitation and communication areas (and there is a big overlap in these two areas of competencies). Several existing competency frameworks in communication management and public relations mark the ability to use modern information technologies as a separate group of required skills (Flynn 2014; Jeffrey and Brunton 2011; Tench and Moreno 2015). Tench and Moreno (2015) discuss the ability to use Web 2.0 tools as part of 'performing' competence of communication managers. Web 2.0 instruments traditionally include blogs, social networking platforms (Facebook, Twitter, and so forth), and other applications for social interaction, business, and education purposes. Jeffrey and Brunton (2011) talk about advising stakeholders on strategic media practices as part of the 'external interface management' competence of communication managers. Today, the Internet is used increasingly in public policy and there are a multitude of approaches to e-participation and e-voting with different ways of engagement (for a group decision-oriented review see e.g., Insua and French (2010)). Overall, interest in using online platforms for stakeholder engagement emerged early in the area of multi-criteria criteria decision support (Hämäläinen 2005; Hämäläinen et al. 2010) and today there is work on related gamification approaches (Aubert et al. 2018; Bakhanova et al. 2020). The fact that people have persistent cognitive biases in decision tasks requires that these challenges are understood by the developers of online support tools (Aubert et al. 2020). When people are remotely connected, the risks of misunderstanding the modeling processes in any approach are particularly high. So strong skills in understanding human–machine interaction are needed together with knowledge of ways to mitigate human biases. The inclusion of web-based material for guidance is not necessarily enough as people often ignore such help. A hybrid approach where a skillful process facilitator is available could be one solution.

Communication competency area has also included such groups of skills as socially responsible communication (Jeffrey and Brunton 2011), ethics (Flynn 2014), supporting/guiding which includes ethical considerations (Tench and Moreno 2015) as well as persuasive communication and lobbying (Jeffrey and Brunton 2011; Tench and Moreno 2015). These competencies are equally applicable to online and face-to-face formats of communications with stakeholders. However, persuasive communication and lobbying should be considered cautiously in the context of PM. As mentioned by a range of authors, a facilitator of PM workshops should keep as much neutrality as possible regarding the topic discussed because such an attitude is compatible with the democratic nature of the PM process and allows all the parties to share their perspectives openly (Vennix 1996; Voinov et al. 2016a, b and others).

4 Survey Research

To further test the findings, we have extracted from literature and author's own experience, we have conducted a survey among PM practitioners. The aim was to gain insight into how they perceive the importance of different competencies and how the scope of these competencies varies across the roles that participatory modelers play through a project. We expect that these results should help to understand the educational needs in the PM field and develop targeted educational programs. The groups invited to participate in the survey represented international groups from different disciplinary backgrounds so that the opinions reflect thoughts across several disciplines, with respondents coming from several different academic communities working on model based decision support, which are not necessarily aware of the work done in the other groups. We want to emphasize that the distribution of the survey was limited, with quite heterogeneous respondents involved, who may have interpreted our questions differently according to their disciplinary background. Thus, the survey results should be considered as insights only.

4.1 Data Collection Instruments and Participants

The survey (Online Appendix 1) has three sections. The first section includes questions related to the demographics, experience, and background of the respondent. The second section is about how the person evaluates herself in different competency areas (i.e., competency profile). At the time of collecting the data the competence framework was not fully completed as for this reason there are minor differences in the names and roles used in the and those used on the questionnaire. The third section asks about how the respondent judges the importance of different competencies varying across different roles assumed in the PM process.

We aimed to reach modelers widely in different communities working interactively with their customers. The survey was publicly available for three months starting in June 2020. Invitations to participate were sent through the mailing lists of the following international scholarly organizations: Modeling and Simulation Society of Australia and New Zealand, Participatory Modeling Community of Practice, International Society on Multiple Criteria Decision making, EURO Working Group on Behavioural Operational Research. Moreover, the survey invitation was announced on the Facebook page of the System Dynamics Society with over 5800 followers. Thus, the invitation reached a relatively high number of modelers. The number of practitioners in these communities is naturally much lower. Many people must have received the invitation through different channels more than once. Naturally, there are many more bodies of researchers, who could have been invited. A comprehensive coverage of any field of research with surveys like this is hardly possible. We intentionally decided not to include any societies or interest groups based on national membership. So, the results only give initial insights of the opinions in the field.

The response rate was very low. We received only 48 fully completed questionnaires. This can reflect a number of things. First, people may have considered the topic of the survey irrelevant to themselves because the umbrella term ‘participatory modeling’ may not be widely used in their particular research community, which, instead would be representing one of the clones of PM, as explained above. This can be the case in particular with the International Systems Dynamics, Multicriteria, and Operations Research communities. It may also be that the invitation letter was not sufficiently motivating, and that the questionnaire was too long and complex to consider. Alternatively, it may be that the low response rate reflects the fact that in reality, very few people in these research communities have experience of practical participatory modeling projects. One explanation can also be that those who are professionally active in practice do not necessarily have time or interest to participate in surveys.

4.2 Results

4.2.1 Respondents’ Background and Experience

In our sample (see Table 1) about half of the practitioners have been involved in less than five projects and the other half were relatively experienced participating in more than five or even ten projects. There are somewhat more male respondents

(58%) than female ones (40%). Half of the respondents are affiliated with universities and others come from government and consultancies. There are no representatives from non-governmental agencies. Almost all use both quantitative and qualitative modeling approaches. There are many different application areas, with environmental problems reported in the highest number of cases. The modeler is the most common role. There are 39 respondents who have been modelers in PM exercises and only 9 have not. 24 people (50%) have been both in the modeler and in the project leadership roles. 29 people have been in both the modeler and facilitator roles. The affiliations of modelers in this sample are: academia—54%, government—3%, consultancy—28% and other—10%. Only 3 respondents have had other stakeholder roles.

4.2.2 Respondents' Self-Assessment

Our respondents were very competent professionals (see Table 2) having good skills in both qualitative and quantitative modeling methods as well as in facilitation and engagement. Naturally we need to keep in mind that this was their self evaluation. In all of the competence areas, we can find at least as many as 65%, and in many areas, there is even a higher percentage, of the respondents who say that they have strong or very strong competencies in that area if we exclude semi-quantitative modeling and designing e-workshops. This does not, however, mean that 65% of the respondents would have such high levels of competencies in all the areas. By filtering the data set we found that there are as many as 14 (29%) who claimed high competencies in all areas. In the whole data set 48% say that they have strong or very strong skills in both qualitative and quantitative modeling. One may notice that the competence areas and the related wordings included in the survey (Table 2) are a little different than those used in Fig. 1. The reason for this is that the survey was carried out first and we used the results when developing the final structure for the competence areas. Notable areas, which were not dealt with in the survey explicitly, include e.g. problem structuring, designing virtual events, transdisciplinarity and systems intelligence.

Over the years there was a growing interest in running PM sessions online (see e.g., Insua and French 2010). Progress has been slow, but it is picking up. In our survey, as many as 34% say that they have strong or very strong skills in the area. This can reflect the very rapid increase in virtual meetings that have become the new normal during 2020 due to the pandemic. Today, running discussion sessions remotely is easy, but there is little evidence that the same simple procedures would be successful when dealing with complex problems building models together with conflicting stakeholders.

Almost all respondents (85% or over) think they are strong or very strong in approaching problems from a systemic perspective, in communicating the results, and in considering the needs of the client. It is interesting to note that there remains only one person if we filter the data and look for people who say that they have all the competencies at levels fair or below. Yet, we cannot conclude from this result that practitioners, in general, would be very strongly qualified, but rather that only those who have answered are real professionals. There are likely many other

Table 1 Characteristics of respondents. Number of completed responses N = 48

	%	N
Age		
18–24	0%	0
25–34	27%	13
35–44	21%	10
45–54	23%	11
55–64	17%	8
65 or over	10%	5
No reply	2%	1
Total	100%	48
Gender		
Male	58%	28
Female	40%	19
No reply	2%	1
Affiliation		
University academic	54%	26
Government	13%	6
NGO	0%	0
Consultant	23%	11
Other	10%	5
Experience-number of projects		
None	0%	0
Less than 5	46%	22
5–10	27%,	13
More than 10	27%	13
Modeling approaches used		
Qualitative (narratives, mind maps, causal-loop diagrams, …)	41%	38
Quantitative (simulation, agent-based, Bayesian, multi-criteria …)	46%	42
Semi-quantitative (fuzzy cognitive mapping, …)	13%	12
Total	100%	92
Application area		
Environment and natural resource management	32%	33
Health	13%	13
Business	13%	13
Defence	8%	8
Energy	12%	12
Organizational development	9%	9
Education	7%	7
Other (agriculture, food, community, engineering, land use, politics, water)	9%	9
Total	100%	104

Table 2 Respondent´s self evaluation of their own personal competencies

Personal skill level	None (%)	Basic (%)	Fair (%)	Low (%)	Strong (%)	Very strong (%)	Strong or very strong (%)
Approaching problem solving from systemic perspective	0	4	10	14	50	35	85
Modeling skills							
Qualitative modeling	2	15	19	36	40	25	65
Quantitative modeling	0	6	23	29	33	38	71
Semi-quantitative	19	25	35	79	17	4	21
Facilitation skills							
Project management							
Building rapport	0	2	29	31	33	35	68
Considering the client needs	0	2	10	12	54	33	87
Communicating results	0	0	15	15	54	31	85
Group facilitation							
Designing the process	0	4	19	23	48	29	77
Managing group dynamics	0	8	25	33	50	17	67
Maintain neutrality	0	4	21	25	50	25	75
Online meeting skills							
Running virtual workshops	17	17	33	67	21	13	34

modelers practicing PM with a more narrow and limited competence profile. One can also speculate that there is a self-selection process where those modelers who have an intrinsic interest and skills in engaging with people are the ones who have become the practitioners of PM. The relevant question is, can anybody learn to become a competent PM professional by suitable training? We think that most likely the answer is positive if one finds the motivation to learn and practice.

We did not ask about competencies in any specific quantitative or qualitative modeling approaches. So, we cannot say anything about the breadth of the modeling competencies of PM practitioners. It is typical that people have their favorite modeling method which they may try to use in all cases (Voinov et al. 2018). Such an approach can lead to inefficient design of the PM process which does not help to resolve the initial problem.

The survey was based on subjective self-evaluation of competencies. Thus, conclusions may not be fully reliable. The risk of self-deception is always present and people are usually biased to overestimate their skills. The issue of knowing if a practitioner really can deliver the competencies is essential when we consider modeling skills. The behavioral issues in modeling are important and can have major impacts on the outcome of the PM process (for related discussions see Hämäläinen 2015 and Hämäläinen et al. 2013). Essentially this refers to the fact that people will use the same models and methods as well as facilitation procedures in their personal way, which can produce different outcomes. Selecting the right method for the case does not guarantee that the overall result will be unbiased.

The distribution of our survey was relatively extensive. As participation was voluntary and the response rate was low, unfortunately, we cannot make any general conclusions about the competence levels of people engaged in PM. The opinions that the respondents provide about the importance of different competence areas are, however, quite relevant and interesting.

4.2.3 Competency Scope

The questionnaire asked to rank the importance of the listed competencies for the roles identified. This was clearly a mistake in our questionnaire design and we should have asked for ratings. The result was that none of the respondents answered correctly by rankings as was requested but replied using a rating mode. The reason for this is likely to be the fact that rating was a more natural way to evaluate the competencies as there were so many alternatives. Another reason can be that the earlier question in the questionnaire asked to rate the own competencies of the respondent. We do acknowledge this clear problem in the data but we think that the data is still of interest to be presented. So we will assume that the respondents really used a 1–5 rating scale where 1 is the lowest importance rating (originally least important on the ranking scale on the questionnaire) and 5 is the highest importance rating (most important in the original ranking scale).

Table 3 shows the percentage of responses where the importance level given is 4 or 5. The highlighted competencies are identified by more than 85% of respondents. Note that project leaders and facilitators have the highest number of competencies which have to be on a high level. Neutrality, systemic perspective, building rapport, and taking client needs into account are necessary skills for both roles. Communicating the results is seen more often to be a must-have skill for the team leader whereas the facilitator is expected to have skills to design the process and manage group dynamics by almost every respondent. The negotiator or mediator role seems to have remained a bit unclear as the skills of designing the process and managing group dynamics are not so often associated with this role.

There is an almost unanimous opinion that the modeler needs to have both qualitative and quantitative modeling skills.

Interestingly, the competence to run online and virtual workshops are seen as important by very many respondents, e.g. 87% think online skills are important for the facilitator. However, as we know today online participation formats and tools are still in very early developmental stages. If we exclude remote collaboration formats, real PM workshops are not yet run over the Internet except in rare test cases (see the recent example of a test case by (Wilkerson et al. 2020).

The results show that quite many respondents think that all of the competencies are important in all the roles. Quite many respondents think the team leader should also have qualitative (39%) and quantitative (25%) modeling skills. So, for these people, a non-modeler would not be a suitable leader. Twenty percent of the respondents also think that even the recorder needs modeling skills. This can possibly reflect the likely fact that most of the respondents in this study are modelers themselves and have likely been in the role of the recorder in their projects. It is very interesting to note what else is expected of modelers. Not more than 52% think that modelers should have strong communication skills and only 44% think they need strong process design skills and even less (36%) think they should be strong in managing group dynamics. This means that more than half of the respondents think that there is, in fact, a need to have people with different roles and skills in a PM project. The current situation where the modeler is likely to act in all the roles is not the ideal one. The facilitator is seen as the one who should be strong in all the non-modeling areas. The result can also mean that if there was a dedicated facilitator then these tasks would fall into her role. But again, we do not really know how many PM projects do have a person playing only the facilitator role. In general, the results suggest that we clearly need more discussion of the roles in PM and possibly also explicitly assign the roles to different people.

The results can also reflect an interest in specialization. The number of respondents was low so definite conclusions are not possible. Bearing this in mind, we have compared what people who think that they are very competent in a certain area, expect of the competencies of people in different roles. For example, among the people who are very strong in quantitative modeling.

- 94% of people say that modelers should have very strong quantitative skills;
- 12% say that facilitators should be very strong in quantitative methods; and
- 22% say that modelers should be very strong in managing group dynamics.

On the other hand, among those who are very strong in managing group dynamics.

Table 3 Percentage of respondents who say that the importance of the competence for the role is on the level of 4 or 5 on the scale of 1–5, where 5 is the highest importance

Roles		Manager/team leader	Facilitator	Modeler	Negotiator/mediator	Recorder
Competence area	Competence					
I. Problem solving	Systemic perspective	85%	85%	79%	55%	20%
II. Modeling skills	Qualitative	39%	60%	90%	22%	23%
	Quantitative	25%	45%	98%	19%	20%
III. Facilitation skills						
1. Project management	Building rapport	91%	86%	33%	67%	24%
	Understanding and consideration of the client's needs, including considerations of the internal and external context	96%	92%	62%	65%	20%
	Communicating results	98%	64%	52%	48%	24%
2. Group discussion facilitation	Designing the process	75%	92%	44%	59%	22%
	Managing group dynamics	68%	96%	36%	67%	29%
	Maintain neutrality in the conflict	81%	100%	59%	76%	50%
3. Online meeting skills	Running virtual workshops	58%	87%	46%	52%	30%

- 100% say that facilitators should be very strong in managing group dynamics;
- 24% say that facilitators should be very strong in quantitative skills, and
- 13% say that modelers should be very strong in managing group dynamics.

Note that this latter percentage is almost half (13% vs. 22%) of that required by those with quantitative skills. Similarly, those who are very strong in group dynamics have higher demands for quantitative skills (24% vs 12%) than those who already have them. This can be interpreted as if modelers should be very strong in modeling and facilitators in managing group dynamics. People who are very strong in the core skill of their role do not find it necessary for people in other roles to be very strong in the same competence even if these people in the other roles themselves do think they need to be. People seem to attribute more importance to those skills that they do not possess.

5 A Strong Call for Better Training

One of the most important signals which came from the survey results is that there is a clear need for more training in facilitation and social skills. People active in PM typically have had their training in modeling and know how to use models. The fact that process skills and facilitation are increasingly emphasized today may lead to a situation where we forget about the importance of core modeling skills. Most importantly, as mentioned above, it is important that participants have some understanding and appreciation of various modeling methods, and are not wedded to only one of them (the 'hammer and nail' syndrome). People can have very limited skills when it comes to mixing modeling approaches in practice. Thus, there can be an important hidden training deficiency in the field, which is the limited breadth of the modeling skills of the PM practitioners. The lack of facilitation and people skills training was clearly voiced by many. Below are quotes from some exemplary statements:

> "It seems we are learning "ad hoc"; and many experienced facilitators and participatory modelers seem to keep their work in a "black box". Methods are usually described in brief in scientific publications, but not enough to make them usable for young researchers as training. Maybe we should start thinking about setting up specific training courses and standards."
>
> "I think that facilitation training needs to be encouraged as well as modeling training. These skills are almost diametrically opposed to that of a modeler, so it is almost crazy to think that modelers can have both sets of skills."
>
> "Project lead role is complex. I'm not sure how to train for it. Specific skills can be learned."
>
> "It would be useful if junior researchers had more training in facilitation and de-escalation. Academic training tends to teach people to fight for their ideas, but facilitation is the opposite -- we want other people to feel comfortable sharing their ideas. (I had one junior researcher destroy a workshop by insisting he was right.)"

6 Conclusion and future outlook

The main goal of identifying the core competencies in PM is to improve the practice of PM. Towards this goal, we had two research questions: *what are the core competency areas and skills required for the PM process? How does the scope of these competencies vary based on the roles that participatory modelers play in the PM process?*

To answer the first research questions, we reviewed and synthesized literature in a wide range of areas related to PM, including soft operations research and Group Model Building. Our synthesis resulted in the identification of five course competency areas: *Systems thinking, Modelling, Group facilitation, project management and leadership, and Virtual participation*. We also specified the subcategories making up each area along with the supporting literature.

For the second research question, to understand how the scope of these competencies may vary for the different roles that participatory modelers play in the PM process, we conducted an online survey that identified the various opinions PM practitioners have regarding the various skills required for the different roles in the process. The results clearly show that the respondents recognize that people engaged in PM do act in different roles and that the range of skills needed is wide. Modeling skills need to be supplemented by social and communication skills. In general, opportunities for training in these skills seem to be missing. These present an urgent future challenge for the field.

Our literature review shows that the richness and complexity of PM implies there is a wide scope of existing competency frameworks that PM could draw upon. This presents a challenge re-synthesizing and organizing this knowledge into a coherent competency framework for PM. One strategy is to consolidate a unified set of core competencies for PM which could then be branched out to connect to other competency frameworks, rather than aim for a holistic framework to integrate all other competency frameworks. This paper presents the first step in this direction, but still more work is needed.

A participatory approach can be useful for the development of a competency framework that involves multiple PM stakeholder perspectives, to develop a view of what is the purpose of this competency framework, and what principles will underpin its development. Another promising venue is to link the identified competencies to pedagogical approaches. Many of the existing courses that teach PM are short and focused on particular case studies or methods (e.g. Systems Thinking and Modelling Practice|UNSW Canberra (adfa.edu.au)). In the absence of some guidelines, PM teachers have to rely on a network of peers, scattered research literature, and much trial-and-error for developing their teaching resources and practices.

In any project, its leadership is essential (Hämäläinen et al. 2020), and one of the main concerns of the project leader should be to see that the project team has the necessary competencies. We should not assume or allow modelers to be in charge of everything. Naturally, the organization of PM projects depends on the size of the project. Smaller projects cannot possibly afford to have different people in all the roles but identifying the roles is still useful. It can benefit the practical organization of the project when people know what is expected of them.

One approach to improving the competencies in a specific discipline is to create an accreditation system and a related training program. This is often organized by professional organizations involved. Examples of accreditations related to PM include the Certified Analytics Professional (2021) and the IAF Certified Professional Facilitator (2021). Running such certification programs needs an organization to support it but universities could also host such programs via distance learning.

As mentioned in the epigraph at the beginning of our paper, we are living in a time where more composite and transdisciplinary skills are required to address the complex problems we are facing. This is clearly the case with PM, which can be efficiently run only by truly composite specialists trained in a variety of disciplines, but, most importantly, have the social skills to apply this training in real life situations. It should be stressed that transdisciplinarity is a skill that is required not only from the full team doing PM, but it should be also present as part of the training of individual team members. We know that simply combining representatives from various disciplines to work together in a multi-disciplinary team can lead to disaster and lack of mutual understanding. In much too many cases we have even seen a certain pride in a discipline to which we belong ("I am not a modeler", "I am not a social scientist", "Social science is just blah-blah-blah"). We still have a tendency to position science as a superior method of inquiry ("the ivory tower") and like to think of scientists as neutral and even more ethical in our work (Voinov et al. 2014). This is hardly helpful for productive PM processes, which require all partners to be equally ready to engage in stakeholder interactions, demonstrating a certain humbleness while doing it. Let us keep in mind that in PM the main goal is improved decision making and management, it is not about advancing science. Science, in a way, is a byproduct of PM.

In the early years of PM, it was mostly a client—provider type of relationship, when stakeholders were engaged largely as clients, users, and the PM exercise was mostly an effort to serve the client in the most appropriate way. This had its influence on the types of competencies that were assumed. For example, Richardson and Andersen (1995) talk of the 'Gatekeeper' role for a person who "is an advocate in two directions: within the client organization she speaks for the modeling process, and within the modeling support team she speaks for the client group and the problem". This seems to be quite similar to the functions that we assume for the 'Team Leader' role, except that in our current prosumer society it becomes increasingly difficult to distinguish between the client and provider. With the growing interest in citizen science and action research, we suggest that PM should be increasingly focusing on team efforts and team management for its success.

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Data availability Survey data used in this research is stored at the internal server of University of New South Wales with access limited to the authors of this paper as per the requirements of ethical application №HC200463 (2020).

Declarations

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Authors and Affiliations

Sondoss Elsawah[1,2] · **Elena Bakhanova**[3,5] · **Raimo P. Hämäläinen**[4] · **Alexey Voinov**[5]

[1] School of Engineering and Information Technology, University of New South Wales, Canberra, Australia

[2] Fenner School, Australian National University, Canberra, Australia

[3] School of Computer Science, Faculty of Engineering and Information Technology, University of Technology Sydney, Sydney, Australia

[4] Systems Analysis Laboratory, Aalto University, Espoo, Finland

[5] Faculty of Engineering Technology, University of Twente, Enschede, Netherlands