Systems Intelligence – Measurement and Modelling

Juha Törmänen

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**Aalto University
School of Science
Department of Industrial Engineering and Management**

Supervising professor

Professor Esa Saarinen, Aalto University, Finland

Thesis advisor

Professor Emeritus Raimo P. Härmäläinen, Aalto University, Finland

Preliminary examiners

Associate Professor Hong T. M. Bui, University of Bath, United Kingdom

Associate Professor Yasuo Sasaki, Gakushuin University, Japan

Opponent

Associate Professor Hong T. M. Bui, University of Bath, United Kingdom

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Abstract

Systems Intelligence (SI) refers to intelligent behavior in the context of complex systems involving interaction and feedback. Systems intelligent individuals and organizations are able to successfully and productively engage with the holistic feedback mechanisms of their environment. This study operationalizes the concept of SI by providing novel measurement and modelling tools and approaches that help take Systems Intelligence from the laboratory to the real world.

The SI Inventories introduced in this study provide both measurement tools and a multi-dimensional conceptual framework for evaluating and discussing how individuals and organizations can succeed in wholes. The study introduces eight factors of SI – Systemic Perception, Attunement, Positive Attitude, Spirited Discovery, Reflection, Wise Action, Positive Engagement and Effective Responsiveness – and argues for their usefulness for individual and organizational development. The dissertation presents and validates inventories for self, peer, an organizational evaluation of SI, and opens new perspectives for discussing organizational learning.

As applications of the framework, the study also presents visualization and simulation solutions for helping people explore and improve their capability to succeed in systemic contexts. Visual displays of individual and team SI scores help people communicate and understand their systems-related strengths and weaknesses, and the Positive Systems Intelligence Teams (PoSITeams) simulator helps to explore socio-emotional systems.

The measurement and modelling tools presented in this work can help to stage interventions for improving individual and organizational capabilities to be more productive within and with respect to systems. The tools also serve as useful instruments for building learning organizations and human resource capabilities.

Keywords Systems Intelligence, Systems thinking, The learning organization

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Systeemiäly – mittaaminen ja mallintaminen

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Systeemiälyllä (Systems Intelligence, SI) viitataan älykkääseen toimintaan monimutkaisissa kokonaisuuksissa, joille vuorovaikutus ja takaisinkytkennät ovat tunnusomaisia. Systeemiälykäs yksilö tai organisaatio toimii onnistuneesti ja tuottavasti ympäristönsä monisuuntaisten vaikutusmekanismien kanssa. Tämä tutkimus operationalisoi systeemiälyn käsitettä esittelemällä mittaus- ja mallinnustyökalut, joiden avulla systeimiälyä on mahdollista viedä laboratoriosta elävään elämään.

Tutkimuksessa kehitetyt systeimiälyinventaarit voivat palvella sekä mittaustyökaluina että käsitteellisinä kehitteinä, kun arvioidaan ja keskustellaan siitä, miten yksilöt ja organisaatiot toimivat monimutkaisissa kokonaisuuksissa. Tutkimus esittelee kahdeksan SI:n faktoria – Systeeminen havaintokyky, Sanaton yhteys, Asenne, Kekseliäs mieli, Pohtivuus, Viisas toiminta, Heittäytyvä osallistuminen ja Aikaansaavuus – ja esittää niiden olevan hyödyllisiä käsitteitä yksilöiden ja organisaatioiden onnistumisen ja kehittämisen kannalta. Tutkimukseen sisältyvät artikkelit esittävät ja validoivat inventaarit yksilöiden itsearvioimiseen, vertaisarvioimiseen, sekä organisaation kyvykkyyksien arvioimiseen.

Lisäksi tutkimus esittelee lukuisia visualisaatio- ja simulaatorratkaisuja, joiden avulla yksilöt voivat kartoittaa ja kehittää kykyään menestyä monimutkaisissa kokonaisuuksissa. SI-inventaarioiden tulosten visuaaliset esitykset auttavat kommunikoimaan ja ymmärtämään kokonaisuuksiin liittyviä vahvuuksia ja haasteita, ja Positive Systems Intelligence Teams (PoSITeams) -simulaattori auttaa ymmärtämään ihmisten välisestä vuorovaikutuksesta muodostuvia systeemejä.

Tutkimuksessa kehitetyt mittaus- ja mallinnustyökalut palvelevat interventioita, joiden tavoite on auttaa yksilöitä ja organisaatioita löytämään tapoja onnistua toimimaan paremmin monimutkaisissa kokonaisuuksissa. Esitettuja työkaluja voi käyttää oppivien organisaatioiden rakentamiseen ja henkilöstön kehittämiseen.

Avainsanat Systeimiäly, Systeemiajattelu, Oppiva organisaatio**ISBN (painettu)** 978-952-64-0467-7**ISBN (pdf)** 978-952-64-0468-4**ISSN (painettu)** 1799-4934**ISSN (pdf)** 1799-4942**Julkaisupaikka** Helsinki**Painopaikka** Helsinki**Vuosi** 2021**Sivumäärä** 170**urn** <http://urn.fi/URN:ISBN:978-952-64-0468-4>

Preface

The work included in this dissertation is based on a period of research beginning in 2010 and stretching all the way to the present day in 2021. During these years, numerous people have contributed in ways big and small for making this dissertation happen; I apologize that I am unable to mention all of you by name here.

I would like to thank my previous and current supervisors, Professor Emeritus Raimo P. Hämäläinen and Professor Esa Saarinen for all the impact they have had on this dissertation and on my life. This dissertation relies heavily on the ground-breaking research done by Raimo and Esa, and both of you have been instrumental in helping the work presented here develop and come to fruition. Furthermore, the growth-mindset, constructively positive life-philosophical approach of Professor Saarinen and the scientifically rigorous, efficient and effective research and communication style taught to me by Professor Hämäläinen have had a huge effect on my personal and professional development. I am deeply grateful for both of you and consider you as some of the most significant persons in the story of my life.

During my studies, I have had the privilege of being a member of two warm and brilliant communities of the Aalto University School of Science; first as a student and employee of the Systems Analysis Laboratory of the Department of Mathematics and Systems Analysis, and later as a graduate student in the Department of Industrial Engineering and Management. I am thankful for the faculty and students of both departments for the inspiring, welcoming, and most of all motivating atmosphere they provided. I am especially thankful for the friendship and interesting discussion opportunities provided by Jaakko Korhonen, Peter Kenttä, Frank Martela, Tuomas Lahtinen, Joonas Ollila, Yrjänä Hynninen, Arttu Klemettilä, Suvi-Tuuli Helin, and Teemu Tiinanen. For Teemu, I am also grateful for his work done for PoSITeams that forms a major part of one of the publications in this thesis.

I am also thankful for all the members of the Systems Intelligence Research Group and people who have participated in Systems Intelligence research seminars over the years, providing viewpoints, thoughts, and approaches for the emerging field. While I cannot mention everyone by name, I would like to especially thank Rachel Jones, Heikki Peltola, Kata Kumpulainen, Riitta Juvonen, Björn Wahlström, Topi Jokinen, Pia Lappalainen, Tuomas Harviainen, Jussi Galla, Lauri Järvilehto, Barbara Malmström, Ari Tervashonka and Henriika

Maikku for insightful thoughts and ideas that have helped this dissertation reach its current form.

I am greatly thankful to the pre-examiners of this thesis, Associate Professor Hong Bui and Associate Professor Yasuo Sasaki, for agreeing and taking the time to act as pre-examiners for this dissertation. Thank you both for your prompt work and the insightful comments you provided in your pre-examination statements!

A large part of the work done for this dissertation has been done part-time while I have been working as Analyst at Crisis Management Initiative and as an entrepreneur and CTO of Inclus. I thank Crisis Management Initiative, especially my manager at the time, Ville Brummer, for allowing me to take a month of time off for finishing my first publication in 2015. I am grateful for my co-founding partner at Inclus, CEO Mikaeli Langinvainio for understanding and allowing me to spend time working on my research in addition to my entrepreneurial duties, and for my colleagues, especially Joonas Rajamäki and Valtteri Frantsi, for helping take some of the work pressure off my shoulders. I hope that my work on this dissertation has not caused you excessive stress over the years!

In large parts, the reason I have been able to do the work of both an entrepreneur and a doctoral student is thanks to the supportive environment provided by my friends and family. Thank you Kaj Sotala and Tuure Laurinolli for your long-time friendship and countless opportunities to ponder our lives together, and to my godmother Liisa Kantojärvi for motivational support and for showing me an example of a very successful doctoral dissertation and defense. Thank you, my mother Eija, father Mikko, and brother Antti for being such reliable and positive fixtures on my life. Most of all, I'm thankful to my partner, Elina, for being a loving and like-minded life companion on this long journey.

Espoo, 31 July 2021,

Juha Tapani Törmänen

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List of Abbreviations and Symbols

CFA	Confirmatory Factor Analysis
DLOQ	Dimensions of the Learning Organization Questionnaire
EFA	Exploratory Factor Analysis
HRD	Human Resource Development
LO	Learning Organization
OSI	Organizational Systems Intelligence
SI	Systems Intelligence

List of Publications

This doctoral dissertation consists of a summary and of the following publications which are referred to in the text by their numerals

- 1.** Törmänen, Juha; Hämmäläinen, Raimo P.; Saarinen, Esa. 2016. Systems Intelligence Inventory. *The Learning Organization*, volume 23, issue 4, pages 218–231. <https://doi.org/10.1108/TLO-01-2016-0006>
- 2.** Törmänen Juha; Hämmäläinen Raimo P.; Saarinen, Esa. *On the Systems Intelligence of a Learning Organization: Introducing a New Measure*. 38 pages. Manuscript revision submitted on 11/2020.
- 3.** Törmänen Juha; Hämmäläinen Raimo P.; Saarinen, Esa. *Perceived Systems Intelligence and Performance in Organizations*. 22 pages. Manuscript submitted on 04/2021.
- 4.** Tiinanen, T., Törmänen, J., Hämmäläinen, R. P., & Saarinen, E. (2016). PoSITeams – Positive Systems Intelligent Teams, an Agent-Based Simulator for Studying Group Behaviour. *Proceedings of the 59th Annual Meeting of the ISSS-2015*. <http://journals.iss.org/index.php/proceedings59th/article/view/2718>
- 5.** Hämmäläinen, R. P., Saarinen, E., & Törmänen, J. (2018). Systems Intelligence: A Core Competence for Next-Generation Engineers? *2018 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE)*, 641–644. <https://doi.org/10.1109/TALE.2018.8615247>

Author's Contribution

Publication 1: Systems Intelligence Inventory

Törmänen is the primary author. Hämäläinen and Saarinen proposed the topic and research questions. Hämäläinen, Saarinen and Törmänen worked together to develop the initial list of inventory items. Törmänen carried out the statistical analysis and wrote the methods and results section of the publication. Hämäläinen, Saarinen and Törmänen jointly wrote the other sections of the publication.

Publication 2: On the Systems Intelligence of a Learning Organization: Introducing a New Measure

Törmänen is the primary author. Törmänen, Hämäläinen and Saarinen developed the topic together, and Törmänen prepared the research design, gathered data, and analyzed and reported the results. Törmänen wrote the methods and results section of the publication. Hämäläinen, Saarinen and Törmänen jointly wrote the other sections of the publication.

Publication 3: Perceived Systems Intelligence and Performance in Organizations

Törmänen is the primary author. Törmänen, Hämäläinen and Saarinen developed the topic together, and Törmänen prepared the research design, gathered data, and analyzed and reported the results. Törmänen wrote the initial version of the publication, which was then further improved on by all three writers together.

Publication 4: PoSITeams – Positive Systems Intelligent Teams, an Agent-Based Simulator for Studying Group Behaviour

Tiinanen is the primary author. Törmänen was responsible for the development of the initial version of the simulation model and the web application, including its visual design. Tiinanen improved on the work to develop the final version of the simulation model, and Hämäläinen and Tiinanen were mainly responsible for writing the publication.

Publication 5: Systems Intelligence: A Core Competence for Next-Generation Engineers?

Hämäläinen is the primary author. Törmänen and Saarinen worked on latter revisions of the article, providing comments, and helping hone its direction.

1. Introduction

1.1 My Personal Path to Systems Intelligence Research

As I joined the Systems Analysis Laboratory of the Helsinki University of Technology (now Aalto University) in 2010, I originally expected to end up working on fairly limited technical simulation models and eventually finding employment writing mathematical software somewhere. Rather, thanks to Professors Hämäläinen and Saarinen, after they picked up my summer work application among a big pile of competing applicants, I found myself at the Systems Intelligence Research Group – a vibrant, multidisciplinary group of researchers working not on a limited technical field, but rather on a truly big idea – that people could and should be able to succeed better in complex situations and environments, that they should be able to be not only individually intelligent and skillful, but also *systems intelligent*.

In 2010, Systems Intelligence (SI) research was maturing from descriptive and qualitative concept-building research to more concrete ideas about providing tools, approaches, and quantifiable metrics to organizational contexts. I jumped in at this point, and soon found myself reading not only systems thinkers such as Peter Senge, but also about positive psychology, management sciences, multiple intelligences theory, psychometrics, and applied philosophy.

The work on SI led me first to work on my bachelor's thesis and master's thesis on the subject, and to also start work on a doctoral dissertation immediately afterwards. However, I soon started to develop a sense that SI isn't something that you become an expert in by simply sitting behind a desk in a university; it's much more valuable to go out to the real world to get some practical understanding, and then write with that viewpoint also in mind.

I was extremely fortunate to get an opportunity to join President and Nobel laureate Martti Ahtisaari's Crisis Management Initiative and to continue working on my doctoral studies during the same time. Travelling to countries such as Egypt, Lebanon, Iraq, and South Sudan and helping to find systems intelligent approaches for different local and regional conflicts and problems also helped me to greatly further my own thinking. Subsequently, I spun off my own technology company, Inklus Oy, with my co-worker Mikaeli Langinvainio, and we have continued the work by helping public and private organizations in Finland and abroad build common understanding and conduct joint analysis. While these detours have caused my doctoral studies to stretch out to span nearly a decade, I sincerely think that this dissertation is much stronger thanks to them.

By way of hindsight, a key reason for my own fascination for working in the SI Research Group was its blend of rigor and relevance, theory and practice. Originally a professor of applied mathematics, Raimo Hämmäläinen had created the Systems Analysis Laboratory as a platform for using mathematics for the purposes of modelling complex structures relevant for engineering. “We serve as systems engineers the science of better”, was one of Raimo’s slogans. There was a strong vision of providing tools for the benefit of actual projects of improvement in the context of real-life operations.

That vision had also led Raimo to invite Esa, a household name in Finland and a philosopher famed for his ability to make philosophy connect with the everyday, to the faculty of the Systems Analysis laboratory of Helsinki University of Technology in 2001. The idea was to use rational judgment and modelling, be that mathematical as with Hämmäläinen or qualitative as with Saarinen, for the benefit of making things work and for improving what didn’t work.

It was in this context of applied science and open-mindedly oriented engineering that I found my intellectual home. For Raimo and Esa, conceptual categories were as secondary as were disciplinary boundaries in contrast to the phenomena themselves. The research on “systems intelligence” was to serve a purpose, and early on I learnt the importance of the “serviceability” of concepts (Burke, 1984; Kenttä, 2020) to be a chief aspect of what we were doing with SI within the university and outside of it. Raimo and Esa often emphasized the “iconic” nature of the phrase “systems intelligence”, through which one enters a perspective that is useful and even fundamental when conceiving of “success within wholes”.

But rational discourse calls for rigorous tools. To that effect, my own work hopes to make a contribution.

1.2 Introduction to the Publications

Publication 1 introduces a core measurement tool of SI, the Systems Intelligence Inventory, and the eight factors of SI. The publication documents the factor analysis strategy that was used to develop the SI Inventory, and validates the 32-item, 8-factor structure for use as a self-report questionnaire inventory for evaluating personal SI-related strengths and weaknesses.

Publications 2 and 3 apply the inventory developed in Publication 1 to organizational and peer evaluations, respectively. Publication 2 uses an “In my organization, people...” worded question to assess the perception of people in one’s organization from the point of view of SI. The publication validates the resulting Organizational SI Inventory and discusses the results in the context of the Learning Organization (LO) and the commonly used Dimensions of the Learning Organization Questionnaire (Marsick & Watkins, 2003).

Publication 3 validates the inventory for peer evaluation in the form “My colleague...”. The publication discusses its relationship with perceived assessment of a colleague’s performance and shows that the SI inventory can also work as part of 360-style evaluations.

Publication 4 discusses the simulation tool, PoSITeams, for helping people understand and improve their behavior in teams and social networks. The

PosITeams simulator is implemented as a web browser -based application to study different social contexts.

Publication 5 takes a more high-level viewpoint, discussing the importance of SI as a general people-related competence needed today even in engineering. The publication suggests SI to be included as a part of engineering education.

While the individual publications discuss and elaborate on specific aspects of SI, together the articles seek to provide firmer footing for the concept of SI as a framework for improvement. Especially relevant is the perspective of the LO, but other contexts of improvement are indicated as well. More generally speaking, the current work contextualizes within research that seeks to incorporate the behavioral with the rational and the theoretical with the pragmatic for the benefit of actual development. It is a humble step towards fulfilling the existential call toward “Being Better Better” (to quote the title of Hämäläinen et al., 2014). In that sense, the current work runs parallel with “behavioral operational research”, another outgrowth of the SI way of thinking (Hämäläinen et al., 2013).

2. History of Systems Intelligence

SI was born from discussions between Professors Raimo P. Hämmäläinen and Esa Saarinen in the early years of the 2000's, after Professor Hämmäläinen had invited Professor Saarinen to join the Systems Analysis Laboratory of the Helsinki University of Technology (now Aalto University). The two professors – Hämmäläinen an expert of systems sciences, Saarinen an expert of philosophy – sparked a dialogue that resulted in the concept.

An especially fruitful forum for the discussion was the emergence of the annual student seminar series called Luovan ongelmanratkaisun seminaari (in English, “seminar on creative problem solving”). Within the seminar, the participants discussed the papers and ideas of both systems scientists such as Peter Senge, Ralph Stacey, Michael Jackson, and Robert Flood, as well as other relevant writings such as Howard Gardner's studies on multiple intelligences (Jones & Hämmäläinen, 2013).

Peter Senge had already widely discussed the importance of systems thinking in his seminal book *The Fifth Discipline* (Senge, 1990), and Senge's work served as a particular inspiration for developing the idea of SI – that it is important to develop and promote the skills of individuals, teams, and organizations to be able to successfully manage and succeed in complex wholes around them.

The term *Systems Intelligence* was coined in the seminar on creative problem solving in 2002, building on the discussion on multiple intelligences of Gardner (1983) and the work on Emotional Intelligence by Daniel Goleman (1995). As Saarinen and Hämmäläinen describe in their introductory essay of SI, *Connecting Engineering Thinking with Human Sensitivity* (Saarinen & Hämmäläinen, 2004a), SI builds on top of these earlier theories and takes a pragmatic and active viewpoint towards real world situations. The article also includes the quintessential description of SI as:

... intelligent behavior in the context of complex systems involving interaction and feedback. A subject acting with Systems Intelligence engages successfully and productively with the holistic feedback mechanisms of her environment. She perceives herself as a part of a whole, the influence of the whole upon herself as well as her own influence upon the whole. By observing her own interdependence in the feedback intensive environment, she is able to act intelligently.

The research seminars on creative problem solving were the central forums for developing the idea of SI further during the early years of the concept. The seminars not only resulted in the term *Systems Intelligence* and many of the core articles about SI, but also gave rise to a series of essays discussing, defining, and describing SI from various perspectives. The essays have been collected into eight volumes, which are publicly available at the Systems Intelligence Research Group web site (<http://systemsintelligence.aalto.fi>):

- Systeemiäly! [*Systems Intelligence!*] (Bäckström et al., 2003)
- Systems Intelligence - Discovering a Hidden Competence in Human Action and Organizational Life (Saarinen & Hämmäläinen, 2004b)
- Systeemiäly – Näkökulmia vuorovaikutukseen ja kokonaisuuksien hallintaan [*Systems Intelligence – Perspectives on interaction and managing wholes*] (Hämmäläinen & Saarinen, 2004)
- Systeemiäly 2005 [*Systems Intelligence 2005*] (Hämmäläinen & Saarinen, 2005)
- Systeemiäly 2006 [*Systems Intelligence 2006*] (Hämmäläinen & Saarinen, 2006)
- Systems Intelligence in Leadership and Everyday Life (Hämmäläinen & Saarinen, 2007)
- Systems Intelligence – A New Lens on Human Engagement and Action (Hämmäläinen & Saarinen, 2008)
- Essays on Systems Intelligence (Hämmäläinen & Saarinen, 2010)

All in all, these collections consist of 126 articles and include contributions from 107 individuals – as such, even in its early stages, SI had an explosive start with a rich, multidisciplinary discussion of its contents and applicability. The essays in these publications discuss SI in various contexts such as teaching, internet security, method acting, mergers and acquisitions, architecture, seafaring, corporate leadership, dialogue, happiness, volunteerism research, and romantic partnerships. The essay collections together provide an excellent lens for the subsequent development of the concept of SI. In the latest volume, *Essays on Systems Intelligence*, published in 2010, Saarinen and Hämmäläinen (2010), paying particular attention to emotional intelligence, suggest an alternative definition for SI:

Systems intelligence (SI) involves the ability to use the human sensibilities of systems and reasoning about systems in order to adaptively carry out productive actions within and with respect to systems.

Since 2004, academic research on SI has been published across multiple topics, such as team dynamics (Luoma et al., 2008), group dialogue (Slotte, 2006), therapy (Martela & Saarinen, 2013), knowledge management (Jones et al., 2011; Sasaki, 2017), engineering education (Lappalainen, 2017), human resources (Nousiainen, 2018), behavioral operations research (Hämmäläinen et al., 2013)

and early childhood education (Hämäläinen et al., 2020). Appendix 1 includes a comprehensive list of SI-related publications.

I personally joined the Systems Intelligence Research Group in 2010, just as SI was starting to take the next steps in its development by developing tools and intervention methods for helping people explore and improve their systems intelligent behavior. We started to look at the possibilities offered by gamification – for example, simulations and games that would provide a low-barrier entry to SI concepts. One result of this work was the development of the “Positive Systems Intelligent Teams”, or *PosITeams* simulator. An early version of the simulator was published in my bachelor’s thesis, and the more mature version is described in Publication 4 of this thesis and detailed later in this summary. Another track led to the development of the SI card game, which helps teams discuss and improve their systems intelligent behaviors, and which is also described in more depth in a later section.

A second major direction was that we started developing measurement tools for SI. The first steps to this direction were taken by John F. Rauthmann (2010) in a series of articles in the *Essays on Systems Intelligence* that lead to describing a version of a trait-based SI scale. Based on this work and further discussions with Rauthmann and the rest of the SI Research Group, we started an extensive project to develop items for a complete Systems Intelligence Inventory.

In Autumn 2010 and Winter 2010–2011, the SI Research Group spent long afternoons in the laboratory, writing, rewriting, and discussing possible phrasings for self-report SI measurement items, and running a long series of pilot studies to assess how those phrasings were understood when evaluated by individuals. The process led from an initial 76-item questionnaire described in my Master’s thesis (Törmänen, 2012) to a final 8-factor, 32-item SI Inventory that was published in 2016 and is included in this thesis as Publication 1 (Törmänen et al., 2016). Most of the research presented in this dissertation is built on top of the SI Inventory factor structure, and its factors and items also serve as the structure of the SI card game.

The ideas of SI have started to become increasingly notable during the past decade. Several articles on SI have been published each year, and SI has served as a framework for many theses and dissertations during the time (these are listed in Appendix 1). The SI Inventory has been applied in practice in various context around the world, for example in Egypt and Australia.

Peter Senge held a keynote presentation at the 30th Anniversary Seminar of the Systems Analysis Laboratory, highlighting the importance of the concept (Senge, 2014). In the speech, Senge uses the concept of “systems intelligence” as a general concept that can be graphed intuitively, rather than as a construct of a theory commanded by experts only. The YouTube recording of this presentation has proven to be widely popular, exceeding 230,000 views at the time of writing this summary (14 February 2021).

Likewise, Professor Saarinen’s annual Finnish lecture series “Filosofia ja systeemijättelu” (Philosophy and Systems Thinking) has helped to popularize the concept, which has started to live a life of its own. The lecture recordings have received over a million views in total (Luoma-Aho, 2021).

A report by the World Economic Forum (2016) on the future of jobs also notes that narrow technical skills are no longer sufficient for success in the “fourth industrial revolution” of the present times. You also need skills such as ability to persuade and teach others, and emotional intelligence. While the report does not use the term SI, much of what it describes as the necessities of the future of work could be tidily summed up with the concept.

In the latter part of the 2010s, much of the SI research has been concentrated around an interdisciplinary research seminar held in Aalto University (and, in the Covid-19 complicated world of 2020-2021, online in Zoom meetings). These meetings have kept up the rich, multi-perspective and multifaceted approach to SI already present in the essay publications, by including presentations from different universities, corporations, entrepreneurs, and writers about how they see SI relate to their own field, or what research they are conducting on SI. These seminars have become a fruitful place for developing the idea of SI and ways to apply SI in practice further.

3. The Factor Models of Systems Intelligence

3.1 Theoretical Background

SI links to various skills in different systems approaches, most notably to the five disciplines described by Senge (1990) – systems thinking, personal mastery, mental models, shared vision, and team learning.

At the same time, SI connects to Howard Gardner's theory of multiple intelligences (Gardner, 1983) and the concept of Emotional Intelligence (Goleman, 1995; Salovey & Mayer, 1990). Gardner's theory and Emotional Intelligence both posit that, when discussing individual capabilities, one should not only focus on simple general intelligence, but rather consider various intelligences and skills required in the modern life. SI can be thought of an additional piece of this discussion – it can be well argued that the capability to act intelligently in complex systemic contexts is essential.

It is worth noting that based on the original definition given by Saarinen and Hämäläinen for SI (Saarinen & Hämäläinen, 2004a) and included in the previous section, SI is better to be considered as a skill rather than a psychological trait. A person's systems intelligence is not something that is fixed from the moment she is born, but rather something that she can learn and develop; it is in the power of every individual to become better at acting in an intelligent fashion in the context of complex and interdependent systems.

To enable that kind of development, it is useful to develop measuring tools that can, at the very least, identify areas of growth for the individuals, teams, or organizations being measured, and preferably also serve as measuring sticks of how much improvement has been done. Thus, an important point in operationalizing SI is to be able to quantify it in some form.

The approach in this thesis is to conceptualize SI as a set of subdimensions or factors that one can develop and excel in; these factors are then used to develop tools that can help people understand SI capabilities better and to identify ways to improve them.

As a quantified model of SI, the resulting Systems Intelligence Inventories serve not only as central tools for systems intelligence interventions and developing SI, but also for related fields such as research on the Learning Organization (LO), as put into motion by Peter Senge. In the recently published Oxford Handbook of the Learning Organization (Örtenblad, 2019), Goh (2019)

provides an insightful discussion and critique of the currently existing approaches for measuring the LO, such as the widely used Dimensions of the Learning Organization Questionnaire (Marsick & Watkins, 2003). More recently, interest in developing bottom-up and multi-level approaches for developing the LO has also been increasing, as demonstrated by Chou and Ramser (2019).

The Organizational Systems Intelligence (OSI) Inventory, described in Publication 2 of this dissertation, provides one additional alternative perspective to developing the LO. When compared to the existing measurement instruments reviewed in depth by Goh (2019), the OSI Inventory takes a strictly bottom-up approach for developing the LO; it focuses on how people behave in the organization rather than assesses how the organization is structured and led. In this, the OSI parallels some of the other more recent developments in the field, such as the psychological safety -based approach of the Learning Organization Survey (Edmondson et al., 2019). The bottom-up approach may help the OSI Inventory serve as a component of more complex models of LO, such as the one suggested by Bui and Baruch (2010).

With the bottom-up approach, the OSI is able to emphasize some of the five disciplines of Senge more explicitly than is the case with the previous LO measurement tools. As is argued in article (2), the approach reported here brings the concept of personal mastery much more strongly to the limelight than previous proposals. As we state in Publication 2, we believe that the OSI is a major step in the operationalization of Sengean insights of the LO.

3.2 Developing the Models

SI is a large concept, and relevant in nearly all areas of our everyday life. It may be sensible to talk not only about SI in general, but also SI in different contexts and organizational environments. Is an individual that is *systems intelligent* in his work life necessarily so in his personal life at her home? Is the team she belongs to at work, or at her hobby, systems intelligent? Could we even describe an entire organization as more or less systems intelligent?

To be able to connect all these different contexts and environments, it is important to introduce shared concepts and vocabulary that can be used to describe and quantify systems intelligent behaviors. Developing the SI inventories described in this thesis, we started with the simplest – an individual self-evaluating their own capabilities – and moved then onwards to also describing teams and organizations, and to validating whether the same vocabulary can also be used for assessing “perceived SI” – that is, an individual’s evaluation another individual, opening the door for also using SI as a component of 360-style evaluations.

The two common approaches for developing a measurement tool are exploratory factor analysis (EFA) and confirmatory factor analysis (CFA), with many applications landing somewhere between fully exploratory and fully confirmatory (Hurley et al., 1997). With a more exploratory development, the researcher begins with less assumptions about the underlying final structure of the data,

and first uses one data set to construct a factor model; with a more confirmatory approach, the structure is hypothesized beforehand, and the analysis is simply used to “confirm” that the model fit the data suitably well.

As Publication 1 (Törmänen et al., 2016) set out to build the first complete inventory of SI, it was natural to use an exploratory approach (Vehkalahti & Everitt, 2019). During the course of building the initial Systems Intelligence Inventory, a pilot set of over 70 items describing systems intelligent behavior was step by step reduced down to an inventory of 8 factors with 4 items each – that is, a total of 32 items. We used a separate confirmatory data set to ensure that the resulting model was valid and reliable in the sense that confirmatory factor analyses, done most often in structural equation modelling (Bollen, 1989), can be.

Publications 2 and 3 build on the work done in Publication 1 by applying the same inventory framework for organizations (Publication 2) and for perceived evaluation of other people (Publication 3). The Organizational Systems Intelligence (OSI) Inventory is discussed within the larger context of developing Learning Organizations, and the perceived inventory is discussed in context of how people perceive each other’s performance. Within these two contexts, an item originally in Publication 1 described as “I approach people with warmth and acceptance” first becomes “In my organization, people approach each other with warmth and acceptance”; then “My colleague approaches people with warmth and acceptance”.

3.3 Factors of Systems Intelligence

The framework of SI described in Publications 1, 2 and 3 consists of eight factors, or subdimensions, of SI, that are used to describe different aspects of systems intelligent behavior. They are defined as (Hämäläinen et al., 2018, Publication 5):

Systemic Perception: Seeing, identifying and recognizing systems, patterns and interconnections, having situational awareness;

Attunement: Engaging intersubjectively, being present, mindful, situationally sensitive and open;

Positive Attitude: Keeping a positive outlook, not getting stuck on negative impressions and effects.

Spirited Discovery: Engaging with new ideas, embracing change;

Reflection: Reflecting upon one’s thinking and actions, challenging one’s own behavior;

Wise Action: Exercising long-term thinking and realizing its implications, understanding that consequences may take time to develop;

Positive Engagement: Taking systemic leverage points and means successfully into action with people;

Effective Responsiveness: Taking systemic leverage points and means successfully into action with the environment, being able to dance with systems.

The eight factors and the ways they relate to our everyday life are discussed in depth in the book Being Better Better by Hämäläinen et al. (2014).

Experimentally, when using the set of measurement items presented in Publication 1, individual SI capabilities seem to strongly vary on these eight factors. For example, a person may be highly skilled in Systemic Perception and Effective Responsiveness but be rather weak in Attunement and Positive Attitude.

The same structure has also been confirmed to work when describing behavior at an organizational level (Publication 2); one can discuss not only individual behavior, but also how people in general behave in the organization.

The 32 items for the self-report inventory, for the perceptual inventory, and for the organizational inventory are included within Publications 1 to 3.

3.4 Grouping the Factors

Eight factors are already quite a lot for keeping in mind at the same time; therefore, at least for educational purposes, it is good to group the factors to make communicating and learning about them easier.

Publication 4 presents one such grouping, where the eight factors are combined into four pairs:

- Perceiving systems:** Systemic Perception, Attunement
- Attitude:** Positive Attitude, Spirited Discovery
- Thinking:** Reflection, Wise Action
- Acting:** Positive Engagement, Effective Responsiveness

There are significant strong correlations between the factors, as described in Publications 1 and 2. Using these correlations and the previous grouping, the factors can be placed to a two-dimensional visualization of the SI inventory so that conceptually and statistically related factors remain close to each other. Figure 1 presents a suggestion for such a visualization.

Figure 1. A grouping of the eight SI factors

4. Tools for Developing Systems Intelligence

4.1 Measuring and Reporting Systems Intelligence

In the approaches described in Publications 1 to 3, the eight SI factor scores are calculated as weighted averages of item scores (with items with negative phrasings reversed). For example, the self-report SI inventory calculates the score for Effective Responsiveness as:

$$EFF = \frac{0.494 * SI29 + 0.666 * (6 - SI30) + 0.473 * SI31 + 0.720 * SI32}{0.494 + 0.666 + 0.473 + 0.720}$$

Where SI29, SI30, SI31 and SI32 are responses to items 29-32, respectively, scored from 0 (“never”) to 6 (“always”). As SI30 was a negatively phrased item, it is reversed in the formula. Using these weighted scores allows analyzing the results in a more fine-tuned fashion; for example, here, SI32 (“When things don’t work, I take action to fix them”) has the strongest weight, meaning that answers to it affect the Effective Responsiveness score more than the other three items.

The Systems Intelligence Self Evaluation available at <http://salserver.org.aalto.fi/sitest/en/> (Törmänen, 2020) reports the results by identifying the factors the participant is relatively strongest in, and the factors the participant is relatively weakest in. This can help the participant both to identify their strengths and to discover his or her most significant opportunities for improvement. For example, a participant might be better than 80% of the participants in six of the factors, better than 60% in Attunement, and better than 95% in Systemic Perception – the evaluation would then highlight Systemic Perception as her strength and Attunement as her opportunity for development.

Figure 2 shows the answer distributions for the eight factors of self-report SI, calculated over all the data gathered from the public self-evaluation questionnaire. Figure 3 shows an example of how an individual’s answers might be reported with respect to these distributions.

Figure 2. Answer distributions of the self-report SI Inventory dimensions (N=3531)

Figure 3. Example of the results page of the self-report SI questionnaire

To date, the Systems Intelligence Self Evaluation has received over 3500 answers that are used to give recommendations to the participant. As Figure 2 shows, the different SI factors have somewhat differing distributions; for example, Positive Attitude has a lower average score and higher variance than Attunement. These differences should be kept in mind when analyzing results from an SI Inventory questionnaire.

Completing one of the SI Inventories consists of answering 32 items with a Likert scale, which takes less than 5 minutes. Thus, the inventories can easily be included as a part of larger questionnaires to incorporate a systems lens to the evaluation.

4.2 Team Visualizations

A typical application of the SI Inventories would be to improve the systems intelligence of a team or an organization. In these cases, the participants may consider their own actions within their working context, and the answer distributions of the entire team are compared to a total distribution of answers. Figure 4 shows one example of such data, with team distributions on all eight SI factors contrasted to the total distributions.

Figure 4. Example of a visualization contrasting smoothed team answer curve (dark teal) to the total answer distribution.

Such a report could help the team identify their relative strengths (in Figure 4’s case, Effective responsiveness and Positive attitude) while highlighting possible avenues for improvement (in Figure 4, the high variance in Attunement and Systemic perception might be cause for worry). Notice that when team distributions are smoothed, such as in this example, large variances in answers may result in a distribution that has multiple distinct peaks.

4.3 Gamification

Publication 4 (Tiinanen et al., 2016) describes one way of using simulations to enhance understanding of phenomena related to SI. The PoSITeams web-based multi-agent simulation provides ways for people to study the dynamics of emotions, building on the Broaden-and-Build theory of Barbara Fredrickson (1998, 2004). The approach was also inspired by the mathematical modelling of marital relations by Gottman (Gottman, 2005; Gottman et al., 1998). The simulation lets people explore how emotional dynamics may affect multi-agent environments such as teams and small social networks, and how different parameters or behaviors may affect the entire socio-emotional system.

While the PoSITeams focuses on exploring the interpersonal dimensions of SI and the effect of positive affect, implicitly it also serves as a tool for people to enhance all eight of the SI factors. People can use it as a tool to conduct “what-if” analyses and ways of exploring what would happen if one changed their own behavior. A manager can also ask what could possibly happen if the teams would be reorganized in a new way. Figure 5 shows an example of the PoSITeams user interface.

PoSITeams

Figure 5. PoSITeams user interface

In addition to these kinds of interactive simulation tools, the SI framework and factor structure can be used in the context of social design games (Harviainen et al., 2016). One such application is the Systems Intelligence Topaasia card deck, shown in Figure 6, which leverages the 8-factor 32-item factor structure of the SI Inventories as a deck of 32 playing cards (Hämäläinen et al., 2020). The card game helps teams reflect on their systems intelligence capabilities and identify ways to develop the teams’ behavior.

Figure 6. The Topaasia Systems Intelligence playing card deck

5. Conclusions and Future Directions

The work presented in this thesis consists of tools and approaches that help bring the idea of SI from the laboratory to the real world. With the development of the measurement and simulation tools described in Publications 1-4, it is now possible to bring SI to empirical application in practice, and to use the shared vocabularies of the three SI inventories to discuss SI-related phenomena in a coherent manner between different application and research fields.

Publication 5 suggests that SI can be a core competence in engineering education. While the publication limits the discussion to that specific field, the SI approach is a general one – the same could certainly be said for other disciplines as well, such as business and management in general.

As this thesis has been long in the making, many applications are already underway. The eight SI factors originally presented in Publication 1 have been used in multiple theses, research projects, and interventions, and much of the recent SI research is built on top of the factors. The SI card game described earlier in this article is one example of such an application that has already been used in a large-scale intervention in early childhood education (Hämäläinen et al., 2020).

The SI Inventories (for self-report, organizational, and peer evaluation) provide new tools that are applicable in various fields. Research and interventions on the LO can benefit from the bottom-up, grassroots approach of the Organizational Systems Intelligence Inventory, and the three inventories can work as a parallel development tool to, e.g., the Fifth Discipline Fieldbook (Senge et al., 1994). The inventories can also help human resource development, as they help to discuss both organizational and individual strengths and weaknesses within the organization.

The validation of the inventories described in publications 1-3 has focused mostly on the factorial and content validity of the constructs; it can now be safely said that the constructs are usable as assessment tools, and that the factors produced are intuitive and understandable in everyday life. Future research on the inventories could focus on their reliability, applicability, and predictive value; how stable do the SI inventory results stay over time? Can SI evaluations predict organizational success, or clearly measure how much an individual's SI capabilities are growing? Is it possible to develop a practically useful "intelligence test" based on the SI factors that would avoid the traps articulated by Keith Stanovich (Stanovich, 2010)?

Another valuable future direction could be to study how the SI Inventories behave in various situations and contexts; is it common that a person may be highly systems intelligent in their work life, but completely systems “unintelligent” at their home life? Are there even differences between various work situations? In this way, it might be interesting to relate the SI inventory research to the recent discussion on situation research and situational psychology (Rauthmann et al., 2015).

The contribution of this thesis is the development of novel measurement frameworks and tools that help operationalize and apply SI concepts in everyday life, both individual and corporate. The SI inventories, for self-evaluation, perceptual assessment, and discussing organizational capabilities, allow conducting measurements and presenting results that help communicate essential concepts and possible needs for change. The visualizations and simulations enable efficient communication of systems phenomena and help make abstract or systemic concepts more easily understandable. My wish is that these tools and approaches help make SI applicable to the everyday life of individuals, teams, and organizations.

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Appendix 1: Systems Intelligence Publications and Writings

This appendix contains known publications, essays, and theses that discuss Systems Intelligence. Publications are listed by year, from oldest to newest.

Articles and publications

- Saarinen, E., & Hämmäläinen, R. P. (2004). Systems Intelligence: Connecting engineering thinking with human sensitivity. In *Systems Intelligence - Discovering a Hidden Competence in Human Action and Organizational Life* (pp. 1–29). Helsinki University of Technology.
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Systems Intelligence (SI) refers to intelligent behavior in the context of complex systems involving interaction and feedback. Systems intelligent individuals and organizations are able to successfully and productively engage with the holistic feedback mechanisms of their environment. This study operationalizes the concept of SI by providing measurement and modelling tools and approaches that help take Systems Intelligence from the laboratory to the real world.

The measurement and modelling tools presented in this work can help to stage interventions for improving individual and organizational capabilities to be more productive within and with respect to systems. The tools also serve as useful instruments for building learning organizations and human resource capabilities.

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