Development of a framework to analyze the impacts of Technology-Based Programs for Migrants' Resilience

Working paper

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Contents

Table of Figures

1 Introduction

This short report discusses research design and methodological issues of implementation and impact research, in particular studying the impact of humanitarian fab labs and similar programs. We aim to raise issues that any research or evaluation design has to make explicit and address, we suggest a few research directions to take, research designs and methodologies to adopt, and we identify important decisions that have to be made.

Impact Research Faces Several Major Challenges

- Social change is slow, e.g. major technological or educational innovations can take several decades to reach maturity and acceptance. For example, Huberman (1973) reports up to a 100 years for global change in education. Minor change can be faster, e.g. the introduction of a new technical artifact may happen within 10 years. This implies that research should be carried out over longer periods. Short term research may contribute to both program design or theory but cannot provide global answers to complex questions like the impact of makerspaces on youth development.

- Programs are complex phenomena, i.e. the number of variables to observe does not allow a global comprehensive impact analysis using experimental settings. Quasi-experimental settings are easier to implement but face threats to internal validity that can be somewhat controlled. It also must focus on a reduced set of questions, i.e. operational variables.

- Correlational research does not prove causality, it requires theory testing approaches that are also difficult to implement (e.g. large N, counterfactual testing and stable panels are required) or – as in quasi-experimental approaches - can only look at partial phenomena.

- Qualitative in-depth research allows gathering interesting insight for program implementation, in particular if it adopts a design research approach. It can suggest new theory, but results cannot be generalized. Like survey research, it also relies a lot on subjective perception that can be somewhat controlled by looking at "objective data".

Executive summary

Goals and major dimensions of study need to be clearly identified, as well as its "operational variables". Only then, can recommendations be made on research design and method (e.g. data collection and analysis).

Meaningful insights in impact research are best obtained by a (mostly) concurrent mixed method approach (Tashakkori and Teddlie's, 2003), since looking at the same phenomenon through different "lenses" can consolidate findings and better identify problem spots in a research design.

In addition, we also suggest carrying out long-term action and design research, in order to help creating programs that are worth observing.

Finally, carrying out research in humanitarian makerspaces requires collaboration from all stakeholders, in particular with respect to data collection.

1.1 Impact research goals and approaches

Research communities often define what is "worth studying" and how. In addition, they usually adopt sets of objectives and rules how to carry out research. According to Kuhn (1996), most research is paradigmatic, i.e. identifies worthwhile general and "asymptotic" research goals and favors certain research designs and methodology. This mechanism influences and limits the scope and nature of what can be studied. We argue that such social constructs also influence what should, can and cannot be done in impact and implementation research.

Impact research and similar fields study phenomena that could be defined with respect to the "implementation loop diagram" (fig 1).

1. **Problem and goal definition:** Problems are identified by various stakeholders and goals are set by various decision-making bodies. They can be revised if necessary.

2. **Implementation:** A program, including definition of operational goals, funding, policies, creation of new structures, etc. is set up and carried out.

3. **Outputs,** refer to elements that are typically looked at in a plan–do–check–act (PDCA) cycle, i.e. an iterative four-step quality assurance (QA) model for continuous control and improvement of processes and products.

4. **Impacts:** Direct effects of outputs and more general outcomes that may or may not interest various stakeholders (e.g. the funding agencies, the program management, participants, society, etc.). Terminology describing various types of impact sis unstable and even contradictory across disciplines.
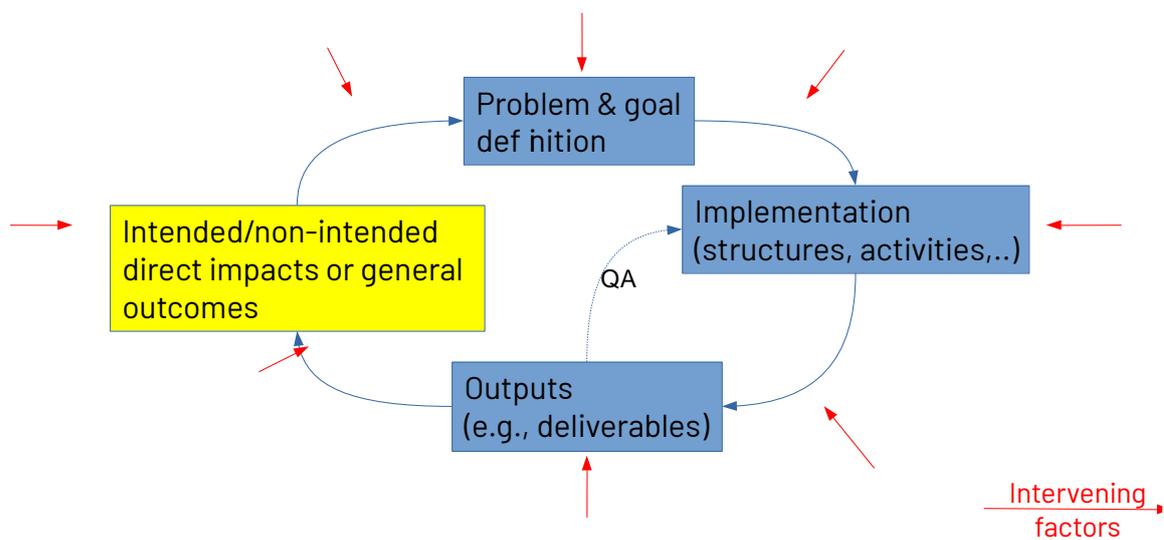
Figure 1 The Implementation Loop

Naive models, popular in evaluation research, assume that problems as well as goals are well defined by some goal setting agency, then implemented more or less, and later maybe revised. Usually this is not the case. Implementation research shows that perception of the problem and definition of goals can be contradictory from the start and that both are *redefined* by the implementing agencies and by the target population (Bussmann,1995). The following picture illustrates this principle:
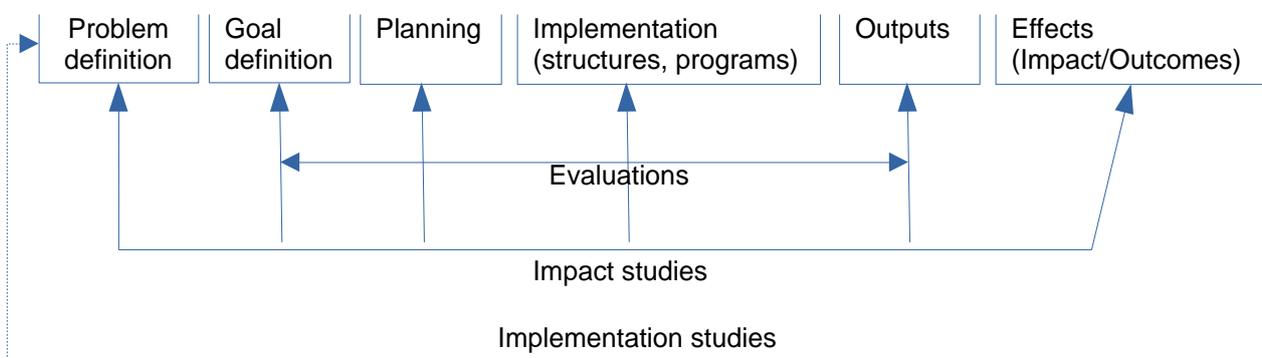
Figure 2: The Implementation Loop Deconstructed

The way in which elements and their interactions are identified (or not) and defined does have an important influence on what will be studied. For example:

- If impact is defined in terms of expected deliverables and measurable indicators, the evaluation will focus on compliance, may ignore more interesting outputs and therefore inhibit the organization from learning.
- A research design that links outputs to impacts without controlling intervening variables may wrongly attribute causality to an intervention variable.
- A research design that focuses on compliance or otherwise expected impacts may ignore or even inhibit innovation.

To sum it, research designs are not neutral, in particular in impact research, since the latter is influenced by policy considerations at all levels as well as disciplinary constraints (i.e. research paradigms).

The ultimate goal of empirical research is to "develop long-lasting theories and unambiguous principles that can be handed off to practitioners for implementation" (Reeves, 2000: 12) However, this principle is of not much help for setting priorities in a subject area where comprehensive studies are very difficult and expensive to implement. We could distinguish between the following kinds of impact and implementation research with respect to their research purpose.

- **Comprehensive empirical field studies.** Implementation research that is interested in the study of all or some outputs, impacts and outcomes whether planned or not. It can either center on "understanding" (theory creating) or be more theory and hypotheses driven. Its aim is to understand the "mechanics" of the phenomenon that was studied.

- **Theory driven studies of a particular phenomenon.** Such studies aim to optimize external validity (generalization), explanation and prediction. Unfortunately, high internal and external validity require a focus on few variables. They either use a quasi-experimental or a correlational (with high N) approach or both.

- **Innovation evaluating approaches.** Evaluation research focuses on measuring in what respect expected outputs, impacts and outcomes are met. It usually has a more practical orientation, e.g. to decide whether funding should continue and whether goals and program elements need to be adjusted. In other words, they usually lack a broader scientific orientation, e.g. problem and goal definition are not part of the research. Less theory is used to explain phenomena that are observed.

- **Innovation building approaches.** Design research or developmental research are forms of so-called action research that focus on creating new "designs" (institutions, policies, programs procedures, etc.) that are informed by theory and empirical research. In particular, in education, "development research requires a pragmatic epistemology that regards learning theory as being collaboratively shaped by researchers and practitioners. The overall goal of development research is to solve real problems while at the same time constructing design principles that can inform future decisions. (Reeves, 2000: 12).

Naturally, there is some overlap, e.g. design research does not exclude evaluation cycles and can include in-depth empirical field studies. Academic implementation research can both inform the former and take data from the former. All research should interact with theory and attempt to explain phenomena as opposed to simply describe them. In other words, practical evaluation research should refer to theoretical explanation and design research should follow and contribute to evidence-based principles.

Therefore, in order to clarify what should be studied and for what purpose, we suggest using a global model that describes a flow model of the implementation process and elements that could be of interest to the

implementation, impact and evaluation researcher. Research then should clearly identify elements of interest and position their research.

1.2   Overview Model of Impact Research Elements

The following model summarizes previously identified elements of both the implementation process and elements that can be studied in impact research. Implementation research extends the focus further, e.g. would also study how problems and goals are defined and how implementation structures are created and implemented.
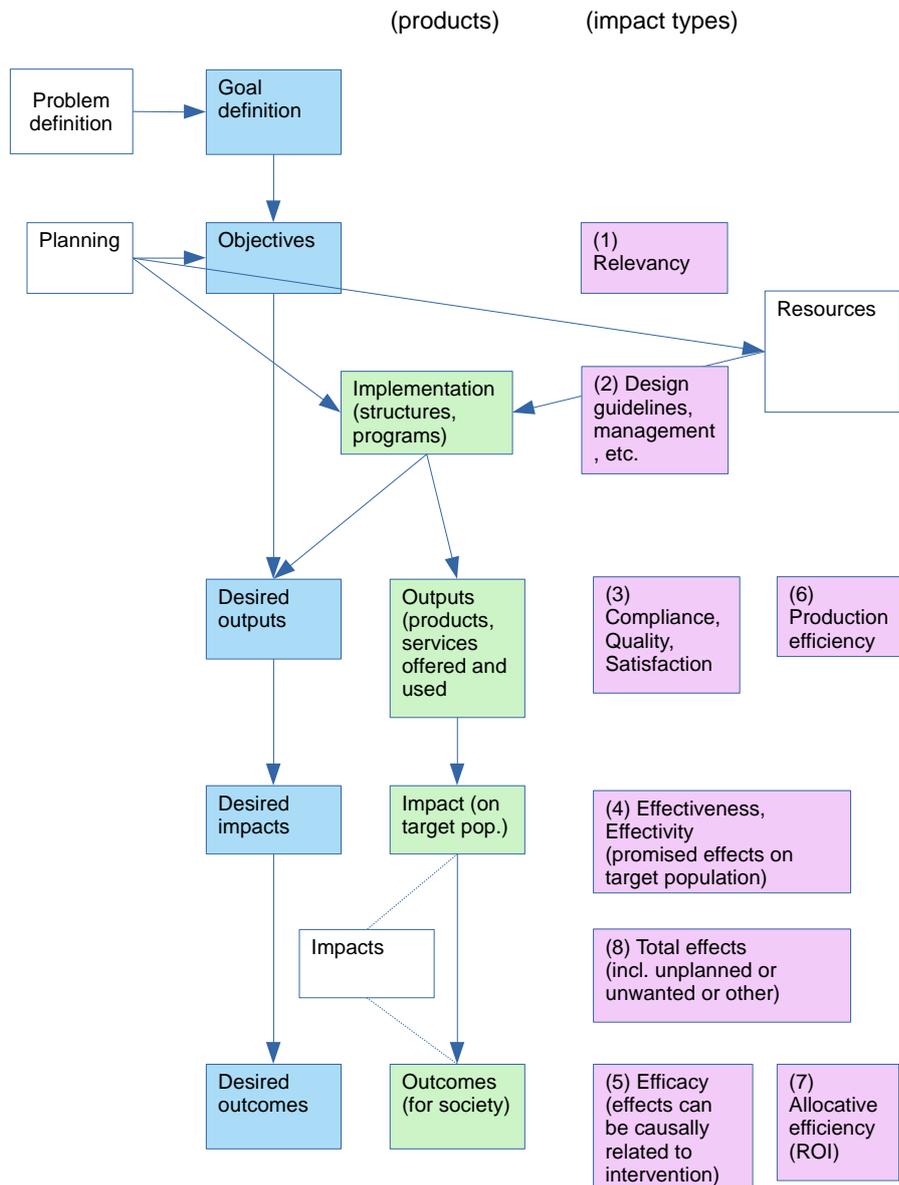
Figure 3 Flowchart model for impact research

2   A model for the study of impact of makerspaces

Before formulating research questions, it is a good idea to create a model that describes major elements of the domain to be investigated as well as relationships between these elements. The following model was proposed to an InZone June 2021 workshop and slightly adapted after the event.
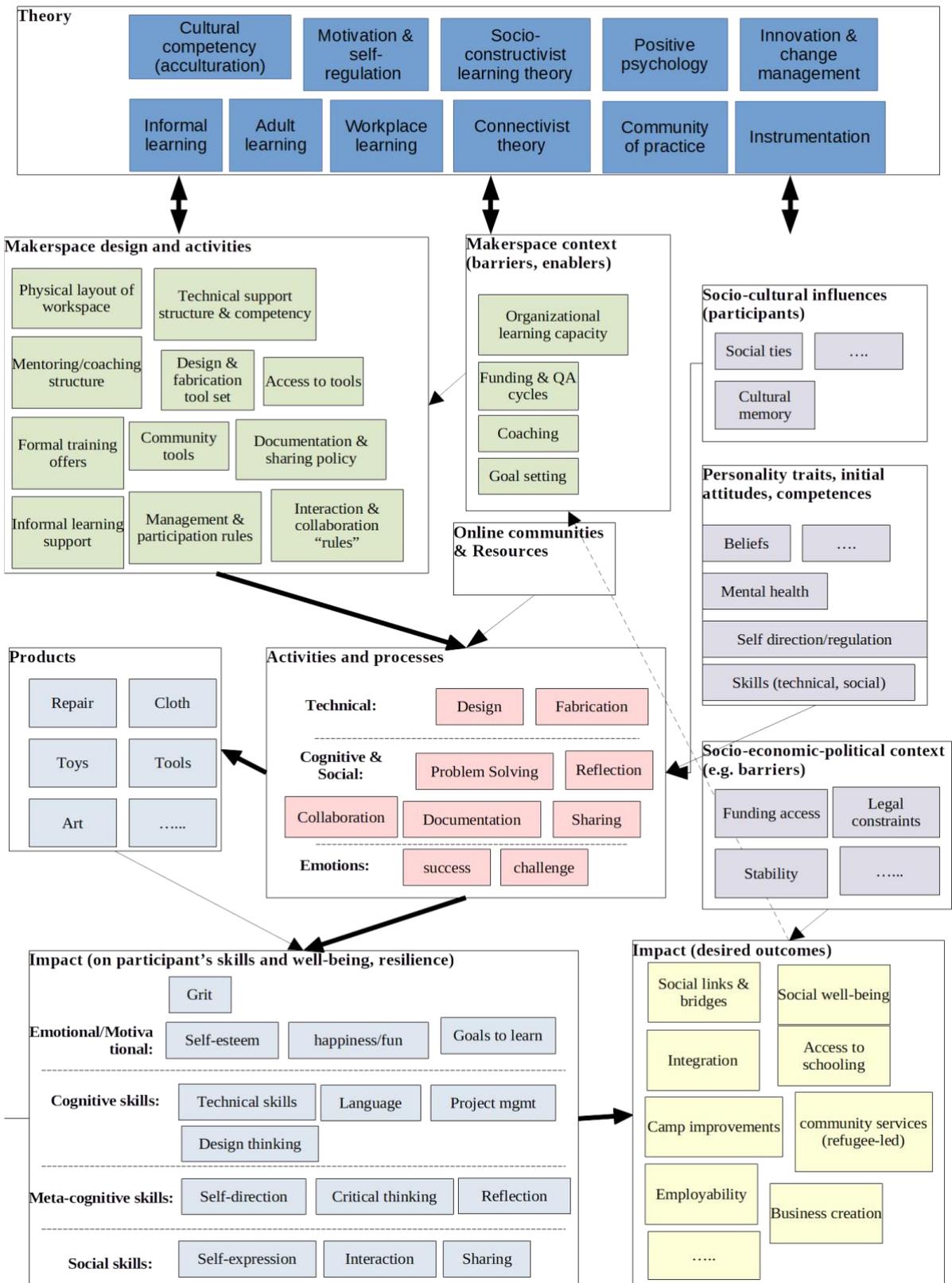
Figure 4: Components to plan impact research studies

Makerspaces implement an interesting technical, social and cognitive trinity (Gantert, 2022). They offer access to technology that individuals can neither afford nor operate alone, they bring together people that share common interests, goals and maybe values and they encourage new ways of social and situated learning.

We distinguish the following elements that could be of interest to the impact researcher.

- **Theory:** Statistical relationships as well as subjective attributions of causality in a typical impact study may not identify deep underlying mechanisms for change. Theory that has been tested empirically (ideally over decades in hundreds of studies) can help both conceptualizing and reducing threats to internal and external validity.

- **Makerspace design:** How should the space be organized in terms of management, policies, participation, infrastructure, activities, etc.

- **Makerspace context**: Relationships with various stakeholders (e.g. donors), local society, etc. Of particular interests are barriers as well as enabling factors.

- **Activities and processes:** Makerspace (and related) activities and processes should be studied in detail in order to better explain impacts (see item below),

- **Products:** What is produced can firstly be used to evaluate a dimension of direct output (is the space used for making?), but also provides clues on what activities, processes and direct impacts to further investigate.

- **Impact on participants:** How do the activities and processes influence participants' emotions and motivations? Do they develop new cognitive, meta-cognitive or social skills?

- **Impact on a larger population**. Can we observe an overall change in the target population as a direct or indirect result of participants' development?

- **Personality traits, attitudes and initial competences:** How do prior "assets" of participants' influence (social) participation and individual change?

- **Socio-cultural context:** How does the social cultural background of participants intervene?

- **Socio-economic-political context:** What are the barriers and enablers?

3   A Short Catalog of Possible Research Questions

Impact studies of makerspaces can be either design-oriented, evaluative, or fundamental research oriented, or combinations. Below we identify a few interesting research avenues (not complete, but hopefully somewhat representative of promising research avenues that could be considered).

Remarks concerning the current state of research:

- Most impact studies **show "that",** ("*what*") i.e., describe various outputs and/or direct and indirect impacts (outcomes)

- Some examine the **"how"**, i.e. activities participants engage in, as well as dynamics of the general makerspace setting

- Few explain **"why"**, e.g., how design and other specific makerspace activities could contribute to cognitive and social processes that lead to individual change and ultimately to social change.

- Impacts are attributed to makerspace activities, but **alternative explanations** are rarely explored, which reduces both internal and external validity.

Remarks concerning future research

- Research goals should increasingly focus on **studying the "how" and the "why"**. Theory should play a bigger role since purely inductive research is threatened by confirmation bias and other social, cultural and political factors.

- Most research questions require **triangulation** since evidence of case studies, even comparative ones, is shaky. Therefore, we suggest using (mostly) concurrent mixed method designs.
- Most research topics **require active participation of makerspace management**. In particular, it is important that traces for activities are created, e.g., pictures with short descriptions of created artifacts, statistics of tool use, journaling of ideas and important events. Development of a common sharing/tracing infrastructure should be discussed (including all sorts of educational makerspaces). But, see the next item.
- There are difficult to address **privacy and ethics issues**. Related to that, there could be more than the usual (already high) unwillingness to participate in research.
- **We suggest that a comparative similar systems approach should be adopted for most research subjects. i.e. several or all humanitarian makerspaces should be analyzed concurrently in one given research.** Differences observed can suggest looking closer at various independent and intervening variables, in e.g. how the makerspace is organized and how participants engage.

3.1 Design of the Makerspace

The following questions are design-oriented, i.e. aim to improve makerspace design via some kind of participative action research

Q: How can we optimize the design of a humanitarian makerspace to achieve X Objectives, given Y constraints?

Since humanitarian makerspaces (as well as educational ones) are very new, little is known about how to design such spaces. This includes formulation of objectives of what is to achieve. Typical questions concern the implementation of "devices" to enhance mentoring and coaching, community building, empowerment of participants. So we firstly need to measure what functionality (structure, policies, activities, etc.) is implemented and how it impacts participants. Then we can enter (re)design cycles. We can also test more specific design elements, like the learning design of training modules.

Methods:

- Participatory action research and observation, including principles from design-based research, i.e. using conjecture maps, creating and refining design rules
- Appreciative quality assessment methodology, e.g. using a grid to summarize progress and various collected indicators.
- Quasi-experimental designs to test the influence of a specific design variable.

Techniques:

- Observation, semi-structured interviews, self-evaluation forms, online traces, group discussions (focus group), participant surveys.

Lightweight design:

- Quality assurance grid that defines objectives to achieve and regular appreciative self-assessment by the management (Plan–Do–Check–Act cycles). The grid should be accepted by all stakeholders, i.e. created with a participatory method.
- Grids are published on a website so that both internal and external participants are informed and may take the opportunity to participate.

Theory:

- Community of practice learning, workspace learning, etc.
- Fablab and makerspace theories that are currently emerging (see e.g. Kraus et al. 2002)

Q: Design of a Humanitarian Maker Program

Participants (from all sorts of backgrounds, but in particular "clients" of humanitarian) action should have the opportunity to obtain a certificate, equivalent to a Swiss CAS for example. That would require international cooperation between humanitarian and other makerspaces plus at least one higher education institution.

Methods:

- Instructional Design Method
- Participatory Design or design science approaches like Stanford's d.school "Design thinking"
- Collection of "objective" data

Lightweight design elements:

- Use Mozilla badges to certify skills that can be achieved. This would require a lightweight common competency framework (an organized list of skills that can be learned). Analysis of badges distributed allow some measure of success.
- Collection and analysis of products (things produced, amount of online exchange)
- (ex-post) self-evaluation and satisfaction questionnaire.

Theory:

- Adult education, informal learning, design science, design thinking

Q: The Makerspace as learning organization

Makerspaces as well as the funding agencies should implement a learning culture that allows innovation (including program adaptation) with the inclusion of all stakeholders (including the "clients"). How can it be done? In addition, we can ask the same question at a network(s) level.

Methods:

- Typical appreciative QA methodology that aims to reach (adaptive) targets, including a light version of methods mentioned in other questions....
- Change laboratory methodology (or similar participatory innovation approaches)

Lightweight design elements:

- Interviews with makerspace management and a few other stakeholders to discuss encountered problems and solutions were implemented or could be implemented.

Theory:

- Expansive learning (Engeström, 2001)
- Reflective Practitioner (Schön, 1983)

Q: How to design makerspace activities that stimulate empowerment and resilience?

Well-being and resilience can be the product of social and cognitive processes triggered by design, fabrication and other activities. For example, self-esteem, self-expression and similar competences are cited in the literature as one of the skills that can be improved through participation in makerspace activities (Dittert & Katterfeldt, 2018; Stickel et al., 2015)

Methods:

- User-centered design methodology (design-oriented action research)
- Experience sampling before, during and after activities, semi-structure interviews, questionnaires (pre-post tasks if no experience sampling, plus pre-post questionnaires over a longer period)

Lightweight design:

- Ex-post satisfaction-type questionnaires that ask participants whether they agree with the positive impact of various activities, e.g. learning gains, self-esteem.

Theory:

- Social cognitive theory, in particular self-efficacy theory;
- Constructionist theory (applied to maker spaces).

Q: Does the makerspace provide access to technology and support?

One of the simple goals of a makerspace is to provide necessary technology to a community. That includes adequate technical and training support. While the question by itself is fairly simple, a working solution is not.

Methods:

- Statistics of use of various tools
- Observations
- Semi-structured interviews with participants
- If scale, questionnaires

Lightweight design:

- Interviews with management
- Satisfaction questionnaire that includes a sample of different stakeholders (participants and non-participants)
- FabLab statistics

Theory:

- Quality Assessment/Assurance

3.2 Impact on individual emotions, attitudes, dispositions, behaviors, and skills

That type of research would ultimately focus on the development of individual well-being and resilience in a wide sense. A large number of subjects can be studied, some of which concern "intermediate variables". Below are a few examples.

Q: Impact of Makerspace Participation on Agency of Change

Participants create their own solutions (bottom-up design) to solve problems they encounter, e.g., missing functionality of the living space, repair of various artifacts, monitoring devices (pollution, sickness, crime, ...). The idea is to see whether in what respect maker spacer can contribute to develop "agency".

Methods:

- Semi-structured interviews, ideally at least twice per interviewee in order to observe change
- Questionnaires (problems, solutions found, appreciation)
- Online traces (e.g., pictures of designs created, number of artifacts produced for each kind)

Comments:

- Makerspace participants must document each production. This process should be as simple as possible since people usually do not like to document their work.

Lightweight design:

- Examination of online traces (requires that each production and tool use is shortly and easily documented)

Theory:
- Repair culture (e.g. Hector & Boterao, 2021)
- Self-reliance theory (e.g. Chapin, 2016).

Q: Impact of makerspace participation on personal empowerment

Makerspaces could contribute to developing a wide range of soft skills and contribute to well-being in a narrower sense, e.g. improve self-esteem, happiness, etc. The challenge would be selecting a reasonable number of dimensions to observe and to carry out observations for the same individuals over a longer period.

Methods:
- Repeated (at least pre/post) survey studies (using standardized instruments, or short versions if several variables are addressed)
- Biographical studies
- Semi-structured interviews
- Participation in online activities

Lightweight design:
- Pre-post questionnaire (based on reduced published scales) plus 2-3 participation indicators
- Stories (short bios) made by either participants or management or both
- Mining of online messages

Theory:
- Various, e.g. developmental psychology, positive psychology, intercultural theory, adult learning ....

Q: Do makerspaces favor acculturation and cultural competence?

Since makerspaces are usually designed as spaces that are open to everyone, does participation favor integration in its various dimensions. e.g. making friends with people from other cultures, making friends with locals, learning other languages, learning the local language.

Methods:
- Questionnaires (sample of the full refugee and local host population)
- Semi-direct interviews
- Observations of the makerspace and its activities

Lightweight design:
- Questionnaire (based on reduced published scales) plus 2-3 participation indicators

Theory:
- Acculturation theory, e.g. Ward & Rana-Deuba (1999).
- Intercultural competence, e.g. Hammer et al. (2003)

Q: Does participating in makerspace activities increase happiness?

Since makerspace activities engage participants in somewhat structured, meaningful and social activity, leading to useful products, they can contribute to happiness.

Methods:
- Experience sampling over a longer period at different times, locations, and events.

- Happiness survey that includes a control population (i.e. a representative sample of all potential makerspace participants).

Lightweight design:

- A "how do I feel today" button at entry/exit of the makerspace
- Experience sampling applications that ask, "how do I feel today".

Theory:

- Happiness theory (e.g. Seligman)
- Positive technology (e.g. Gaggioli)

Q: Do makerspaces contribute to learning new skills?

Digital design and fabrication require specific skill sets that must be acquired. We can distinguish between specific core skills as well as additional skills. More generally, one could study if participants achieve some kind of "technology literacy" that includes design and fabrication.

- Use of various machinery
- Use of digital design tools
- Information literacy
- Language skills
- Project skills
- .....

Methods:

- Certificates delivered, e.g. achievement badges (should be on the to-do list of the makerspace network)
- Pre-post questionnaires
- Interviews
- Statistics: e.g., Admissions to schools, business activities created, jobs landed

Lightweight design

- Badges obtained (requires a badging system)
- Surveys
- Success stories (through interviews with management and if possible the participants)

Theory:

- Design and technology education (e.g. de Vries et al., 2020) or making education
- Adult learning

Q: What do participants learn and how?

This question is addressed by several interesting case and comparative case studies, although the focus is on the "what" (e.g. Corsini et al. 2019,2020). One could aim to identify a list of items learned (attitudes, knowledge, applicable skills, etc.) including a variety of soft skills. Such studies can also aim further and study learning activities and identify the mechanisms through which participants learn.

Method:

- Pre-post surveys measuring technology skills (i.e. ICT literacy plus making literacy) plus tangible soft skills.

- Interviews

- Observations

- Traces of activities and things produced

Lightweight design

- Open-ended questionnaire "what did you learn"? And "How?"

Theory:

- Making (fab lab) education (see design & technology education)
- Making in education (e.g. Bell et al., 2010; Blikstein, 2013)
- Learning sciences

Q: Which variables explain success?

Success in this context refers both to the acquisition of skills promoted by makerspaces (see above) and improved well-being in a wide sense. Development of skills and well-being is influenced by many factors, e.g. personal traits, personal attitudes and skills, cultural elements, etc. It even can be argued that Makerspace activities can be substituted by other activities that trigger similar cognitive and social processes. In other words, demonstrating that specific makerspace variables do have an impact is difficult.

Method:

- First: Qualitative interviews and in-depth multidisciplinary literature review

- Survey study across a large and diverse population that attempts to correlate perceived activities (makerspace and others) with perceived change, mediated by personal factors. Better, "perceived change" should be replaced by repeated surveys (costly and difficult!) Causality can be tested with linear models such as structural equation modeling.

Lightweight design:

- Video or voice interviews where makerspace participants answer a few questions regarding their global experience. Completed with semi-directive interviews with other key persons.

Theory:

Since this a very complex question, multiple theories have to be considered. For qualitative comparative case studies, I suggest an ethnographic approach that can be fairly theory-free in the beginning. For quantitative correlational studies, see all the other suggestions. See also the next suggestion (creating a model)

Q: Can/should we create a general model of (humanitarian) makerspace learning?

Such a model should focus on the most interesting variables and their relationship, in particular ones that are specific to informal social learning that engages participants in making (see above), for example:
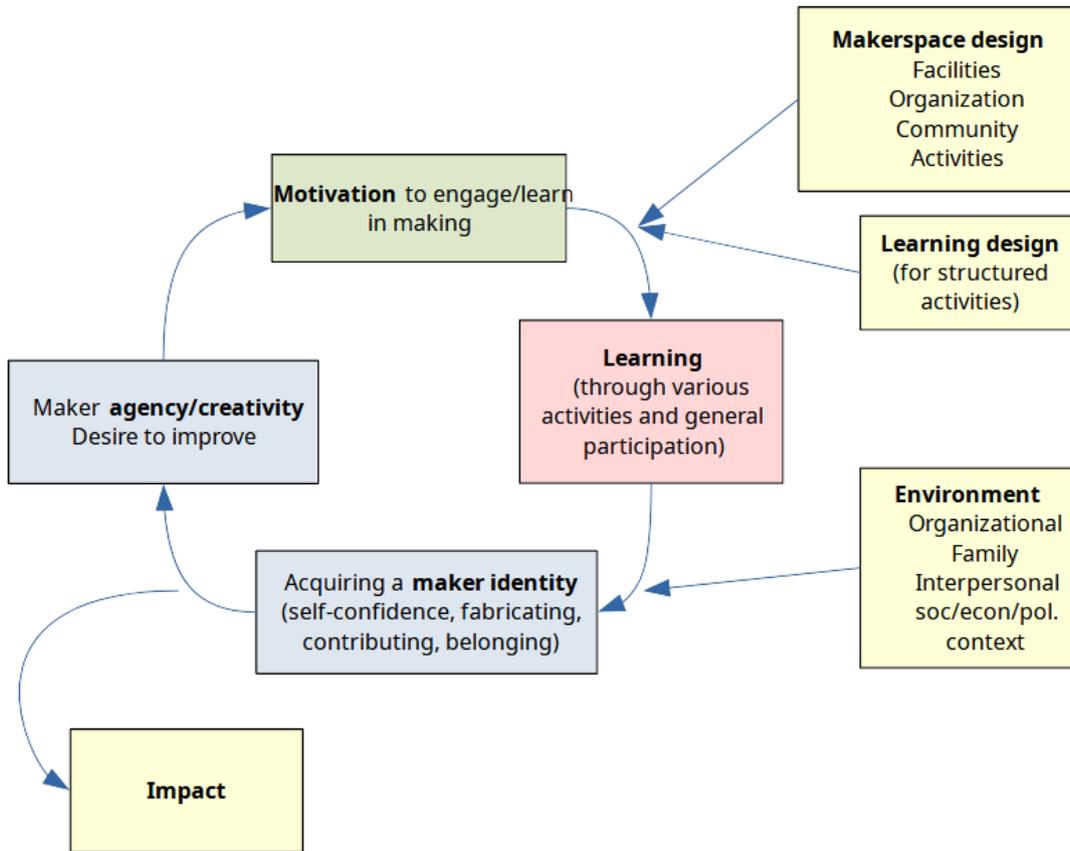
Method:

Figure 5: Model of makerspace learning

- Mixed-method design combining semi-structured interviews, system variables, objective data and survey instruments

Light-weight design:

- Semi-structured interviews with participants and key stakeholders plus some observations.

3.3   Impact on the community

Q: Do makerspaces contribute to improved living conditions?

The makerspace is used to make repairs and useful artifacts (including the use of "standard tools").

Participants can and do express their needs and will become enabled to answer some of their needs.

Methods:

- Statistics of tool use
- Items produced (if appropriate)
- Semi-structured interviews and/or questionnaires (participants, makerspace persons and target population as a whole)

Lightweight design:

- Analysis of traces (requires that tool use is documented)

Theory:

- Self-reliance (e.g. Chapin, 2016)
- Emancipatory development and immigration theories (to some extent)

Q: How well are local innovations adopted by a community?

Community can be understood as the "client" community (e.g. refugees), the local native community and various support groups. User-led design tends to lead to community buy-in, sustainability, and easier scalability. (Betts & Bloom, 2014).

One major reason to promote humanitarian makerspaces is to improve local conditions of living, e.g., improve interior design, create specific instruments (e.g., water filtration), repair/improve structures, etc.). These capacities can then also be (re)used by the host community.

Methods:

- Online traces (e.g. pictures of designs reused)
- Interviews (participants and makerspace persons)
- If scaled, questionnaires to the community.

Lightweight design

- Interviews with management, other agencies and community leaders

Theory:

- Immigration / migration / cultural competency theories

Q: Does a makerspace have an impact on business creation and jobs?

It is argued that makerspaces can be an incubator for small business activities. In addition, technical, intercultural and soft skills acquired may help find a job. Such perspectives are ambitious and may require more formal training programs. In addition, legal, political and other external hurdles may be high. However, in the long run, refugees must engage in some kinds of economic activities within or without the camp.

Methods:

- Official Statistics if available
- (Short) questionnaires to find candidates, then interviews
- Interviews or semi-open questionnaires

Lightweight design

- Interviews with management, other agencies and community leaders

Theory

- Quality assessment

Q: Do participants create their own personal learning environments and communities

Engaged participants are likely to create their personal learning environment, in interaction with others, either local or on the Internet. Some resources of the makerspace (e.g. official documentation) may be underused because they feel comfortable and more efficient with other resources and creating their own communities of practice.

Methods:

- Interviews
- Observation (while they design / work on something)

Lightweight design:

- Interviews with both participants and makerspace personnel.

Theory:

- Emancipatory pedagogy (e.g. Freire, 1993)
- Informal learning theory (e.g. as in the reader of Conner & Clawson, 2004)

4 Overview of research approaches and methods for impact research

Impact research and evaluation methodology does not differ from other empirical research methods. However, focus and context can be different. For example, impact evaluation focuses more narrowly on determining if a project benefits the addressees and if it is worth supporting and therefore includes a utilitarian goal. We will start describing a few challenges.

4.1 Major Challenges of Impact Research

Impact research faces several challenges. We shall address the four major ones: (a) the time frame (b) the difficulty to demonstrate causal relationships, (c) participation and (d) political issues

a) Timeframe for innovation and change management

Innovation and change management require long processes. e.g. in education, a well-managed change program for a single organization takes 25 years on average, if well managed (Burkhardt & Schoenfeld, 2003). Change problems observed in education are probably similar for this area of study, i.e. humanitarian makerspace design. Systemic change at a global level can take much longer than 25 years. Successful programs involve all stakeholders, manage to create a common vision and coach individuals for general professional development.

b) Threats to Internal and External Validity

To create causal explanations, it is usually suggested to carry out quasi-experimental research, i.e. the effect of an intervention in a group is measured and then compared with control groups.

Quasi-experimental design suffers from severe threats to internal validity (Campbell and Stanley, 1963). For example, testing effects (e.g. straw fire), statistical regressions, auto-selection of participants, maturation (subjects evolve without treatment), history (other events do cause change). Adopting a comparative time series approach can control some of these factors, i.e. one should compare between experimental and non-experimental groups and use a series of pre- and post-treatment measurements.

Correlational research is even more problematic, in particular if the main instrument is survey research. It focuses on what participants perceive (e.g. what they believe they did and how, as well as change in various attitudes and beliefs). However, if combined with quasi-experimental research it allows testing a wider range of hypotheses.

Qualitative research allows to gain much insight in the "mechanics" of a studied phenomenon, but cannot provide much external validity, i.e. findings only describe the mechanics of the local implementation being examined. These can inspire other implementations, i.e. help to create and revise design principles, but cannot be generalized with certainty.

Research can be combined in a mixed methods approach (Tashakkori & Teddlie, 2009), i.e. a design that triangulates different ways of studying the same phenomena. For example, learning effects could be measured by looking at artifacts produced, tests, survey questions that measure both what participants claim that they do and their impression of learning, qualitative in-depth interviews, biographical studies, etc.

c) Participation in research and evaluation studies

Being able to select representative participants is a major difficulty.

There are several issues, e.g.:

- Difficulty of finding participants

- Sampling (random selection problems)

- Privacy rules that the research design must obey

- Mobility (participants dropping out of longitudinal research)

Ideally, the communities addressed should find an interest in the study being carried out and also be able to formulate desiderata. This way we may hope that participation rate increases and dropout rate decreases.

d) Political Issues

Impact studies can be delicate since they are expected to match either positive or negative expectations. To put it more bluntly, impact studies are often either expected to produce evidence that support programs or that allow killing them. In addition, as we pointed out before, if carried out as an evaluation, the focus is either on output or direct impact and therefore may not address global outcomes. Also, focus may be on official bodies and procedures and not informal ones.

Besides these major methodological issues, a number of other problems can arise and that should be managed. Figure 6 attempts to provide an overview of challenges as well as their interactions.
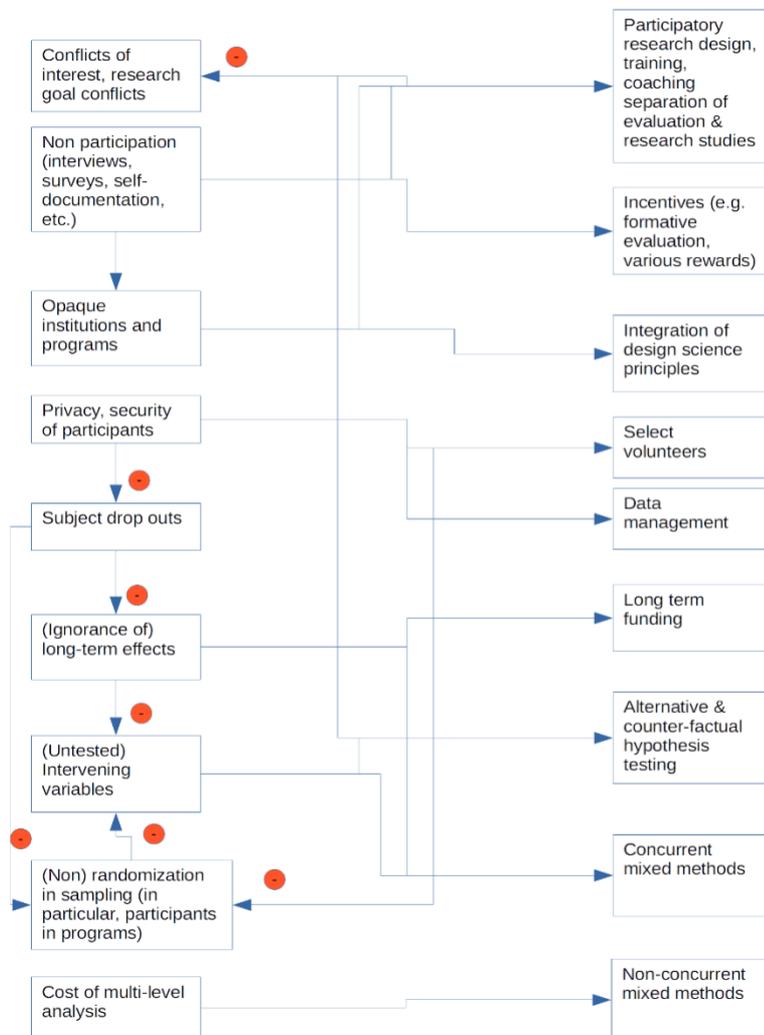

Figure 6 Challenges to impact research and possible solutions

Methodological problems related to sampling or other internal validity issues can be somewhat addressed by using mixed methods, e.g. by looking at the same phenomena with different methods and different data.

Political problems can be lessened by adapting an inclusive user-centered design-based approach where all stakeholders are encouraged to exchange and to create common language as well as shared goals.

Lack of time may the most challenging issue. It should be addressed by (1) long term funding and (2) creating of communities that allow keeping in touch with a moving population.

4.2 Research designs

A research design defines how research questions should be answered, i.e. defines a global methodological approach which then can be carried out using various lower-level research methods and techniques.

4.2.1 Overview

According to research types discussed in the beginning, we could distinguish between an explanatory/predictive approach, a descriptive/comprehensive approach and design-oriented transformative approach (which is closer to comprehensive). Often a mixed methods approach is used for impact research.

Each type of global approach favors certain research designs.
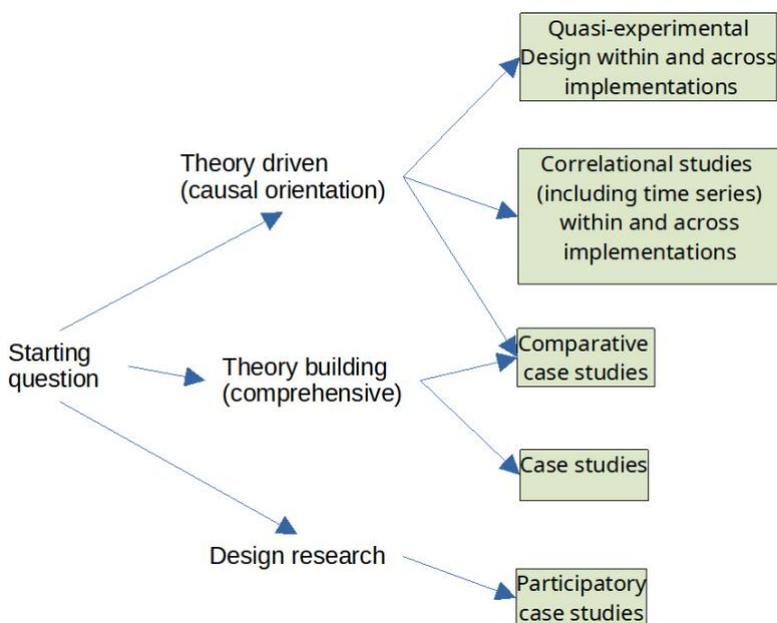
Figure 7 Major research orientation and research designs

For each research design, a certain amount of research methods and techniques is needed. Globally, theory-driven research favors quantitative methods, whereas theory building and design research favor qualitative methods. This is, however, not a requirement. For example, quantitative data mining, analysis and visualization can very well contribute to bottom-up theory building or structured qualitative interviews can be used for theory-testing.

The next figure relates types of impact and implementation research to research designs at a finer level. It also includes evaluation studies which in terms of methods can use both quantitative and qualitative data, but usually in relatively simple way, e.g. pre-post comparison of various indicators plus qualitative insights.
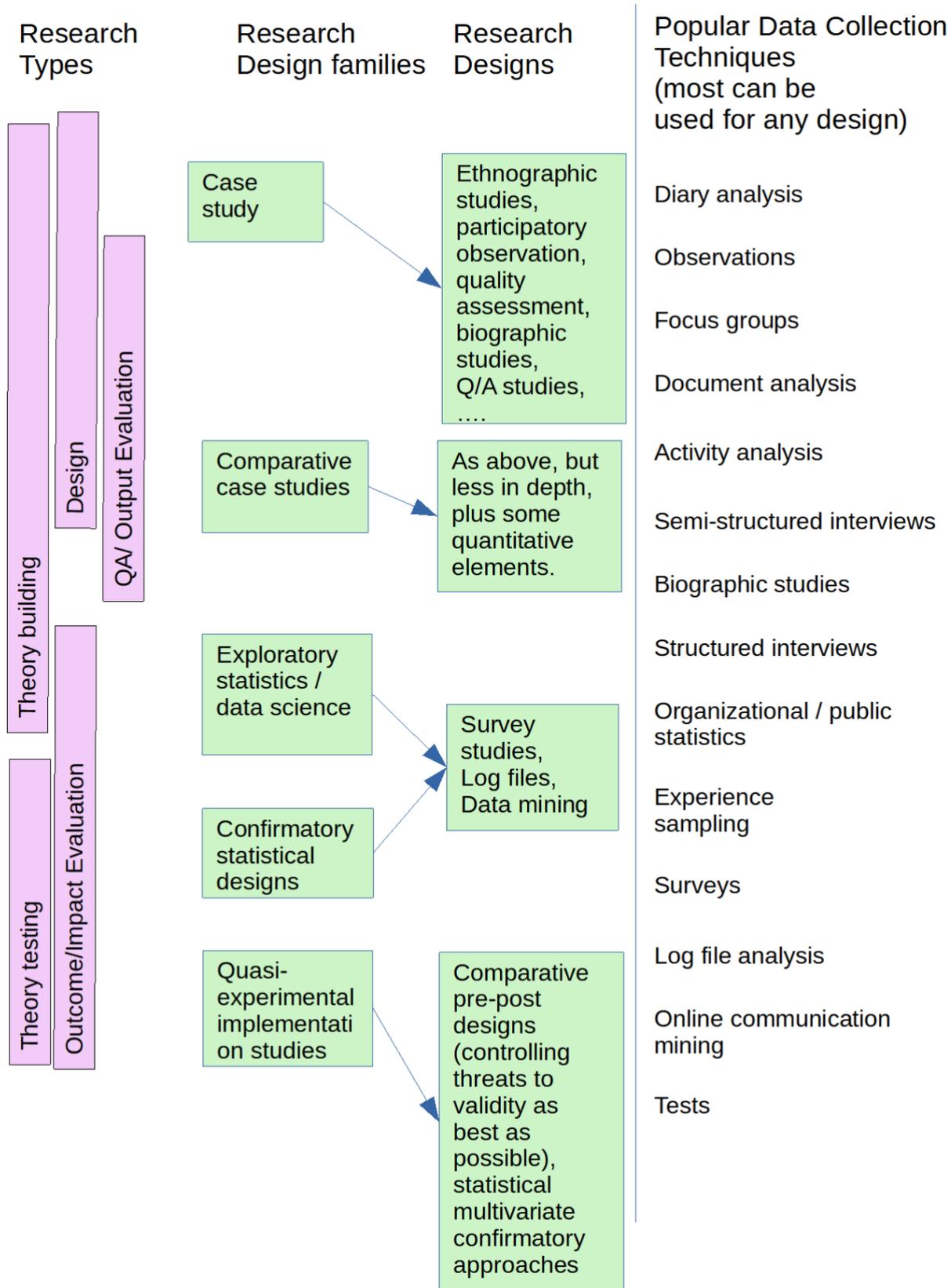
Figure 8 Major research orientation and research designs

Below we shortly define the two dominant families of research designs.

4.2.2 Quantitative explanatory (predictive) approaches

Most quantitative theory-testing approaches in impact research seem to adopt some kind of quasi-experimental design but some studies are correlational. Both can complete each other. We distinguish between two types of quantitative research:

Quasi-experimental pre-post comparative designs

The principle of experimentation is that randomly selected (if possible) participants are given a "treatment". Impacts are measured over time (at least before and after) and compared to a control group. Since randomization of makerspace participation is probably neither realistic nor desirable for ethic reasons, we can compare (a) different types of participation and (2) different "natural groups", i.e. different locations. Quasi-experiments are not experiments, in particular, participants are not randomized, treatment is not clearly identifiable, and many non-experimental variables can intervene. Cook & Campbell, Donald T. (1979) identified major threats to internal validity and strategies to cope, in particular, they suggest that at least comparative pre-post designs should be used.

More recent literature describes fairly sophisticated methods. For example, Khandker et al. (2009, p 27) distinguish seven evaluation approaches to Ex Post Impact evaluation. Their handbook includes a good list of case studies mentioned in the text and in summarized in appendixes.

1. Randomized evaluations
2. Matching methods, specifically propensity score matching (PSM)
3. Double-difference (DD) methods
4. Instrumental variable (IV) methods
5. Regression discontinuity (RD) design and pipeline methods
6. Distributional impacts
7. Structural and other modeling approaches

All these approaches deal with the central question of selection bias, i.e. how to avoid threats to internal validity. They do not address issues of external and construct validity.

Statistical confirmatory designs

Statistical designs using both survey data and objective data (if privacy considerations allow to link data sets) can test certain specific hypotheses, e.g. the impact of maker activities on "personal" variables (emotions, self-regulation, etc.) .

Pre-post designs give better results, since participants are not asked how they perceive the evolution of what they do, think or feel, but rather what they (think they) do, think and feel at a given moment.

Typical analysis uses multivariate linear models such as multiple regressions or structural equation modeling (SEM).

4.2.3 Qualitative Theory Building Approaches and Methodologies

The main aim of such approaches is to find out "how things work", as opposed to "that" they work and "why" they work.

According to the Sage Encyclopedia of Qualitative Research Method, there exist various catalogs of qualitative empirical research: "John Creswell outlined five methodological approaches to qualitative empirical research: narrative research, phenomenological research, grounded theory research, ethnographic research, and case study research. Similarly, Norman K. Denzin and Yvonna Lincoln discussed several sources of, and techniques for, gathering empirical data: observation, interviews, analysis of cultural and archival records, visual methods, autoethnography, data management and analysis techniques,

computer-assisted analysis, focus groups, applied ethnography, and conversation and cultural analyses."
(Given, 2012).

The same source also argues that qualitative approaches can contribute most to various forms of impact research, e.g. "Evaluation research is applied in that the aim is to produce knowledge that will contribute to greater understanding of the effect of a defined activity. This activity may be referred to in a number of ways such as intervention, initiative, and policy. An intervention is a specified, but not necessarily specific, activity. It may already be in place or may be a new type of activity. Evaluations are often set up when interventions are being initiated or when unexpected problems arise. It is considered as important to find out what interventions do and do not work and also how things work or what prevents them from working. In this way, lessons can be learned and taken forward in future attempts to improve the social world in which we live. Developing knowledge of how things work is where qualitative research has a particular contribution to make to evaluation" (pages 303-304). In that sense "The goal of evaluation in this approach is to understand the relationship among context, mechanism, and outcome." (p 3.04).

4.3   A note on research quality

Research quality is usually defined by various types of validity and in addition, usefulness and reliability of data collection methods:

- Is it useful: Does it answer a question that is relevant to society and/or the target population
- Internal validity: Can we exclude alternative explanations of postulated causal effects
- External validity: Can we generalize?
- Construct validity: Do indicators measure what they are supposed to?
- Catalytic validity: Does it engage participants?
- Reliability: Do data collection techniques and measures lead to identical numbers when repeated in a same situation (and maybe by different researchers)?

Impact research is concerned by all of these levels: usefulness, validity and reliability. Recommendations:

- Reduce confirmation bias by testing counterfactual hypothesis.
- Confront findings to theory (in particular, if the research is not theory/hypothesis-testing driven).
- Triangulate. In particular, confront perceived data and subjective meaning with "objective" data.
- Do not overgeneralize case studies and comparative case studies.

5   Annexes

5.1   Typology of research

Related to the identification of what should be studied is the way in which research should be carried out and its purpose. We can distinguish between (1) empirical research (2) design sciences and (3) evaluation science. Figure 3 shows a slightly modified taxonomy by Järvinnen (). It first makes a distinction between empirical studies and philosophical ones. At a second level, empirical studies divide into two major strands "focused on what is reality" and "innovation and evaluation". At the third level, in our context, we may distinguish between empirical studies, innovation building and innovation evaluating. The latter two can, but must not, contribute to theory creation.
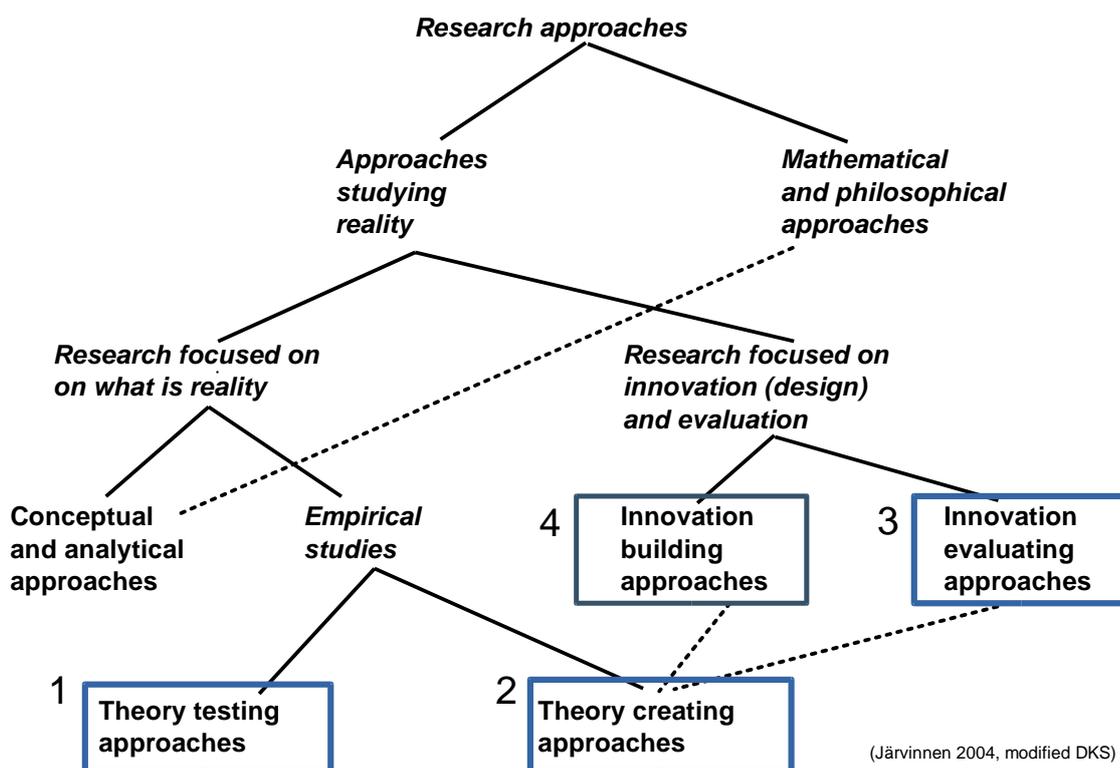
Figure 9 Järvinnen taxonomy of types of research

Selecting a **purpose of research is not innocent** since research purpose will not only require different research designs but also influence what is being studied. We could distinguish between the following kinds of research with respect to purpose.

- **Empirical studies (1-2):** Implementation research that is interested in the study of all or some outputs, impacts and outcomes whether planned or not. It can be either comprehensive (theory creating) or theory driven and testing of hypotheses. The ultimate goal of empirical research is to "develop long-lasting theories and unambiguous principles that can be handed off to practitioners for implementation" (Reeves, 2000: 12).

- **Innovation evaluating approaches (3):** Evaluation research focusing on measuring in what respect expected outputs, impacts and outcomes are met. It usually has a more practical orientation, e.g. to decide whether funding should continue and whether goals and program elements need to be adjusted. In other words, they usually lack a broader scientific orientation, e.g. problem and goal definition are not part of the research. Less theory is used to explain phenomena that are observed.

- **Innovation building approaches (4):** Design research or developmental research are forms of so-called action research that focus on creating new "designs" (institutions, policies, programs procedures, etc.) that are informed by theory and empirical research. In particular in education, "development research requires a pragmatic epistemology that regards learning theory as being collaboratively shaped by researchers and practitioners. The overall goal of development research is to solve real problems while at the same time constructing design principles that can inform future decisions. (Reeves, 2000: 12).

Naturally, there is some overlap, e.g. design research does include evaluation cycles. Academic implementation research can inform both of the former and take data from the former. All research should interact with theory and attempt to explain phenomena as opposed to simply describe them. In other

words, practical evaluation research should refer to theoretical explanation and design research should follow and contribute to evidence-based principles.

Therefore, in order to clarify what should be studied and for what purpose, we suggest using a global model that includes both a flow model of the implementation process and elements that could be of interest to the implementation, impact and evaluation researcher. Research then should clearly identify elements of interest.

5.2 Perspectives in Impact Research

The terminology of what we mean by "impact" or "evaluation" research is not very stable. However, most authors distinguish between observable program outputs and outcomes/impact that affect the target population and or the society. In terms of success, we find return on investment questions (efficiency) and effectiveness (how much has been achieved). Terminology we shall use is based on various authors that study policy implementation from larger perspective. e.g. Knoepfel et al.'s of sustainable program evaluation model makes a distinction between program, action plan, output, impact and outcome. This vision is shared by most of the public policy research community in Switzerland. e.g. "als Outputs werden hier die Produkte der Verwaltung, als Impacts die Auswirkungen auf das Verhalten der Zielgruppen/anvisierten Kunden und als Outcomes die gesellschaftlichen Auswirkungen bezeichnet" (Bussmann).

Evaluation and impact research focus on one or more of the following dimensions:

Outputs

- defined as products produced by the program, i.e., the hypothesis that an intervention produces what was promised.
- In terms of evaluation: **compliance**, **efficiency** of operation, **user satisfaction**, etc.
- Outputs are typically observable products and services created
- Output evaluation is often at the core of quality assessment, i.e. it is measured to evaluate compliance with what was promised.

Impacts

- defined as the **direct impact on the target population**, i.e. the hypothesis that an intervention has an effect.
- In terms of evaluation: **effectiveness, effectivity**.
- Impacts are typically a change in the behavior of the target group

Outcome

- defined as the **impact on a larger construct such as the society**, i.e. the hypothesis that there is a causal link between change and an intervention.
- In terms of evaluation: **efficacy, return on investment.**
- Impacts are typically macro-sociological changes such as higher employment, increased feeling of happiness, ...

A word of caution. There is no general agreement on what "impact" means. Often it includes what we called outcome above. Or the other way round, "impacts" are called "outputs" (e.g. Peters, D. H., Adam, T., Alonge, O., Agyepong, I. A., & Tran, N. ,2013).

Impact research that extends beyond program evaluation distinguishes between planned or wanted impacts and outcomes, and other unplanned or unwanted impacts. Typically, funding agencies may not be interested in positive effects if they are not planned.

Table: Types of impacts and outcomes

	wanted	**unwanted**
planned	changes that are related to objectives	minimized side effects
not planned	positive side effects, other effects	important negative side effects

Evaluation of impact can be part of organizational learning efforts, innovation or change management, policy making, etc. An academic impact study is usually more focused on "what is" and "why". It can choose any subject of interest. Implementation research, for example, would study the process as a whole, include the genesis of the problem perception and goal setting. Learning sciences would study the mechanism and the impact of program activities on participants.

However, the distinction between practical and academic impact research is blurred and we also can identify a few other criteria that allow discriminating between different types of impact research:

- **Two basic objectives for evaluation studies:** Formative evaluation vs. summative evaluation.
- **Two basic targets:** Evaluation of an organization vs. evaluation of a program
- **Moments in time:** Strategic evaluation (defining what should be evaluated and how), process evaluation (how things are being implemented), outcome evaluation.
- **Two extremes:** implementation research considering all aspects vs. output evaluation
- **Two implementation visions/strategies**: Top down (administration) vs. bottom-up (local/"street" actors). How do participants engage in data collection models, data collection and interpretation is an issue that should be addressed.

5.3 Dimensions that can be evaluated in Impact Research

Let us define various *evaluation* dimensions, but keeping in mind that impact research is not reduced to evaluation research: evaluation of outputs, impacts and outcomes are just one type of phenomenon that can be addressed. In any case, a major effort will have to be made in order to define what outputs and impacts shall be evaluated. As we stated above, there are "different worlds" that are usually not compatible. Below are a few evaluation dimensions:

Pertinence (relevancy)

- Can the purpose of the program be justified?

Effectiveness (fr. effectivité, de: Effektivität)

- Effectiveness can be described as the promised effects that can be observed in the target population. From a different perspective, how well was a planned action to achieve planned goals implemented, i.e., does it match observable behavior.

Efficacy (fr: efficacité)

- Promised effects can be causally related to the intervention. Can we relate observable impact to program activities?

Efficiency (fr: efficience, efficacité; de: Effizienz/Wirtschaftlichkeit)

- Return on investment, i.e., the ratio between invested resources and outputs, impact and outcomes. Some authors define efficiency in a narrower sense, e.g., the relation between allocated resources and outcomes.

- In a wider sense "Verhältnis zwischen dem vorgesehenen oder tatsächlichen Output und den vorgesehenen oder tatsächlichen Ressourcen (Wirtschaftlichkeit der Outputproduktion) bzw. Verhältnis zwischen den voraussichtlichen oder tatsächlichen Outcomes/Wirkungen und den vorgesehenen oder tatsächlichen Ressourcen (=outcomebezogene Wirtschaftlichkeit)." (Bussman, 1995).

Production efficiency (fr: éfficience productive)

Ratio use of resources / outputs

Allocative efficiency (fr: efficicience allocative)

Ratio resources / effect (impact)

The dimensions above do not define any substance but help define what should be studied. Once research goals and questions are set, a first effort has to be made to identify "variables" to be studied, indicators that can measure these variables and select appropriate research designs and methods. For example, in an educational program we could carry out:

- Training evaluation (acquisitions, skills, knowledge)

- Operational evaluation (professional behaviors, skills, change, improvement projects)

- Strategic evaluation (operating conditions, collective performance, benefits)

and then look at effectiveness, efficiency, quality, impact, and satisfaction for each, using a mixed methods approach (Tashakkori & Teddlie, 2009).

As we noticed above, evaluation is just one dimension and impact research may focus on other issues, explain the way a program is implemented.

5.4   List of interesting theories

5.4.1   Cultural competency and acculturation

Intercultural competence can be examined through the lens of cognitive, affective, and behavioral (CAB) dimensions. This paradigmatic approach focuses attention on such personal variables as tolerance of
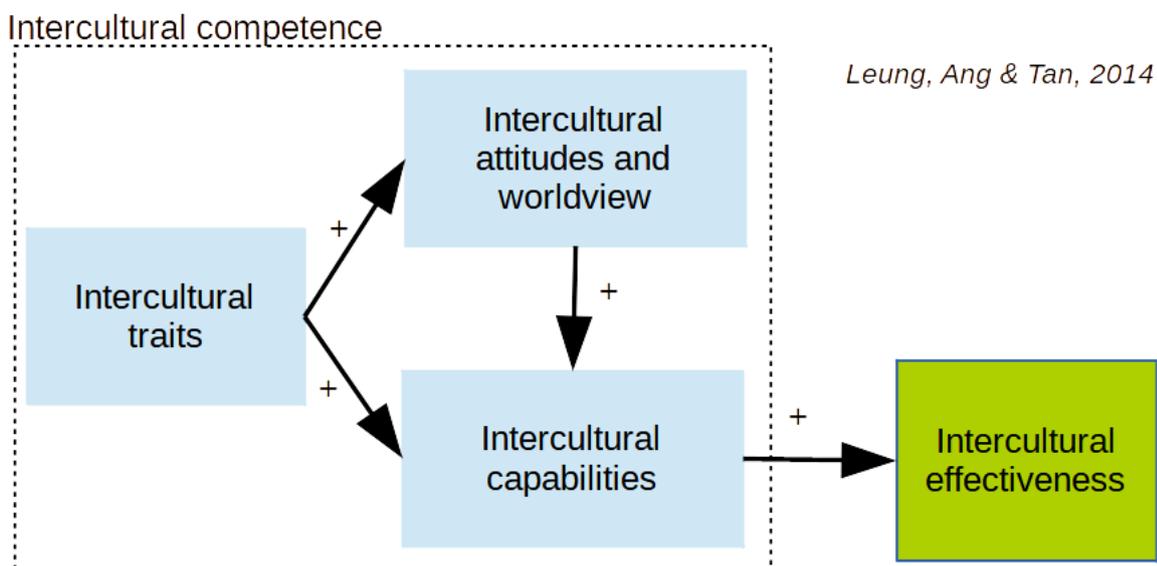

Figure 10: Intercultural competence

ambiguity, open-mindedness, and behavioral flexibility. Such theory could explain for example why a given group of persons increase their well-being better than others or why they engage more in makerspace activities.

Leung, Ang & Tan (2014) define intercultural effectiveness as being a result of intercultural competence. This component view of what intercultural effectiveness does not explain how it develops.

Therefore, another approach is to look (inter)cultural competency in terms of developmental models as well as "intelligence". Cross et al. (1998), in the context of workplace diversity, laid the foundation of many further studies that have a behavioral and developmental orientation and that also have more practical aims: "Cultural competence is a set of congruent behaviors, attitudes, and policies that come together in a system, agency, or among professionals and enables that system, agency, or those professionals to work effectively in cross-cultural situations". For Sam and Berry (2010), acculturation "refers to the process of cultural and psychological change that results following meeting between cultures. Closely linked to acculturation is adaptation, which is used in this article to refer to individual psychological well-being and how individuals manage socioculturally. Adaptation is thus considered a consequence of acculturation." Acculturation strategies refer to the various ways in which groups and individuals seek to acculture. (Berry, 1974, 1980).

5.4.2   Motivation & Self-Regulation

Motivation is a need or desire to reinforce a behavior or to orient it towards a goal (Myers) In simper terms, Motivation can be defined as the reasons that push someone in his action. Motivation is a kind of vector. It triggers specific activities in a certain direction with a necessary intensity and ensures their continuation until the end or interruption. Motivation and self-regulation theory can explain individual achievement differences. It can also be used a way to look at the motivational impact of various activities.

It is possible to distinguish between two broad classes of motivation to perform an activity: intrinsic motivation and extrinsic motivation. A person is intrinsically motivated if he performs an activity for no apparent reward except the activity itself. Extrinsic motivation, on the other hand, refers to the performance of an activity because it leads to external rewards (e.g. status, approval, or passing grades). (Deci, 1972, p.113).

Extrinsic rewards lead to extrinsic motivation but can also undermine intrinsic motivation

Of particular interest is achievement motivation (Myers & De Wall, 2020, p. 1150) which can be defined as the "desire for significant accomplishment, for mastering skills or ideas, for control, and for attaining a high standard". That type of motivation is closely related to grit, i.e. self-discipline Duckworth (2016) plus self-control.

Malone & Leper (1987) identified two groups of variables that increase intrinsic motivation: Individual
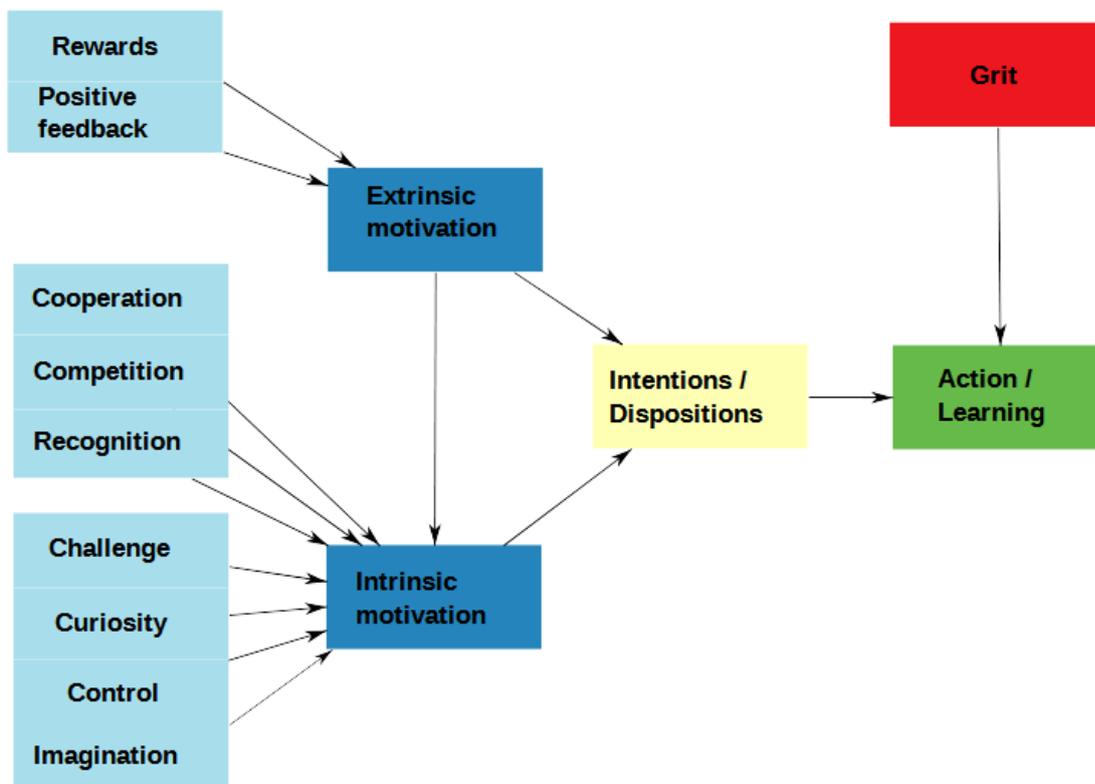
Figure 11 Motivation model for informal learning

(challenge, curiosity, control, imagination) and interpersonal (cooperation, competition, recognition).

5.4.3   Cognitivist learning theory

Cognitivist learning theory is based on a rational information processing model of the human mind and makes a distinction between different types of memory, e.g. Short-Term Sensory Store (STSS), Short Term or working memory (STM), and Long-Term Memory (LTM) (Atkinson and Shiffrin. 1968) Mayer's (2001) popular multimedia model adds a distinction between auditive and visual channels. Each multimedia input goes through several processing stages; auditive and visual input are processed differently, but must be integrated with long-term knowledge in order to achieve understanding.
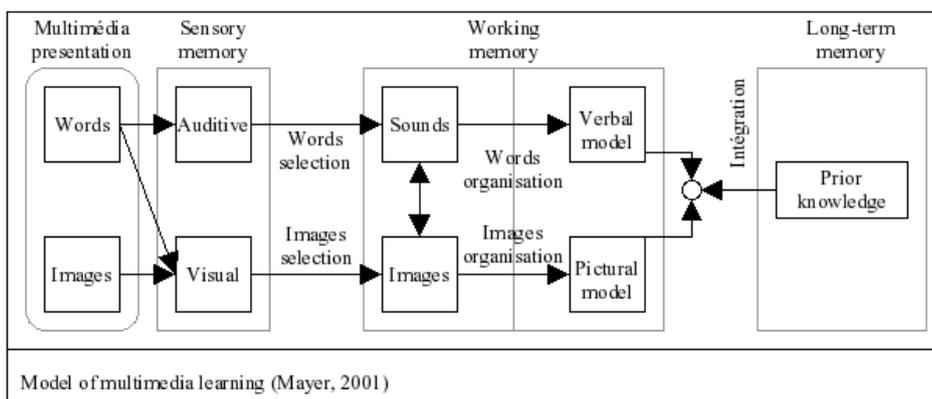
Figure 12 Cognitivist learning theory

Cognitivist theory is tied to cognitive load theory which "is concerned with the design of instructional methods that efficiently use people's limited cognitive processing capacity to apply acquired knowledge and

skills to new situations (i.e. transfer). CLT is based on a cognitive architecture that consists of a limited working memory with partly independent processing units for visual and auditory information, which interacts with an unlimited long-term memory." (Pass, Renkel & Sweller, 2003).

Cognitivist learning theory is relevant for designing instructional materials and training courses in two ways: Appropriate combination of media and minimization of unnecessary or excessive load.

5.4.4   Socio-Constructivist Learning Theory

Socio-constructivist learning theory incorporates influences traditionally associated with sociology and anthropology, socio-constructivism emphasizes the impact of collaboration and negotiation on thinking and learning. A central notion in socio-constructivism is assisted learning, a concept that is influenced by socio-culturalism and its concept of proximal learning. A variant also includes situatedness, i.e. the interaction with the social and physical context.

Learning in making communities can be best be analyzed and explained with some kind of social learning theory, i.e. its "mechanics" of socio-cognitive conflict, proximal learning, situated interaction with objects, etc. Observations would focus on both social and physical interactions.

5.4.5   Positive Psychology

Positive psychology describes highly productive states of mind such as "flow". Some research is interested in how this state can be achieved through the design of learning activities. (Heutte et al., 2016). We can formulate that some types of making activities favor flow, which is also described as "optimal learning experience". Flow is favored by activities that have clear objectives, provide immediate feedback and some kind of equilibrium between difficulty of tasks and individual competency.

5.4.6   Innovation & change management

Innovation and change management theory attempts to understand how change happens, what elements hinder or enable change, and how change can be engineered.

The diffusion model of Rogers (1962) suggests that adoptions of new products take a bell-shaped curve. Initially, only a few innovators will use it (2.5%), followed by 13.5% of early adopters. In Moore's (1991) more pessimistic model (see Figure below) there is a chasm between the early adopters (technology enthusiasts and visionaries) and the early majority (pragmatists).
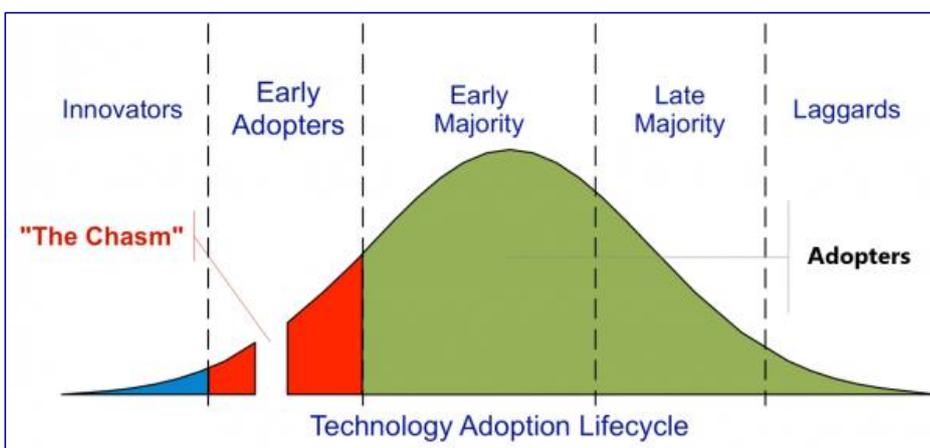
Figure 13 Moore's technology adoption life cycle

Technology acceptance models (Davis, Bagozzi & Warshaw, 1989) state that the use of a system can be predicted by its perceived usefulness and ease of use. The latter are in turn influenced by diverse external variable. The figure below represents the first edition of the TAM model for which now exist several more complex variants, which add other variables such a persons' computer self-efficacy and perceived facilitating conditions.
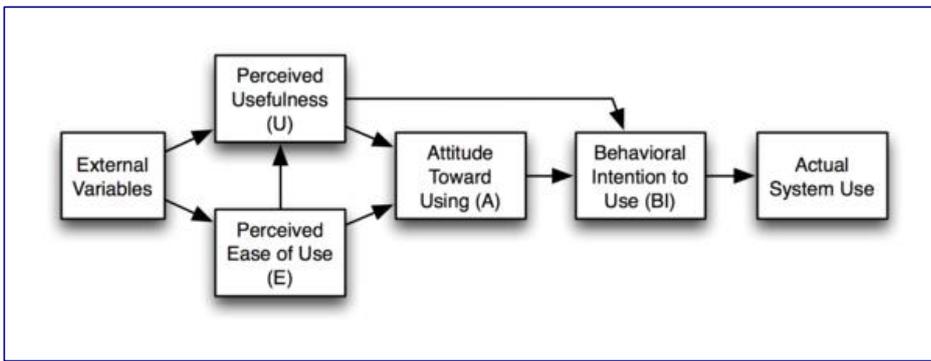
Figure 14: Technology acceptance model (TAM) (1989). (Source: Wikipedia)

Approaches and methods to facilitate change do exist, e.g. most design sciences favor some sort of user-centered approach where an external expert team works on designing policies, programs and implementations together with all the stakeholders. There exist specific methods, such as Engeström et al. (1996) "Change lab".

5.4.7   Informal Learning

Various informal learning theories propose frameworks on how to describe and analyze learning activities that occur in the workplace (see below, in makerspaces and other settings that are not school. We can distinguish between several forms of informal learning, e.g. incidental learning, non-formal learning and informal learning.

5.4.8   Migrant's use of technology

There exist several types of studies of migrants' use of technology E.g. Collin & Karsenti (2015) distinguish three cases:

- migrants using technology to prepare for the migration
- migrants using technology to maintain links with the source society and to integrate into the host society.
- Adaptation of the technology in the above process.
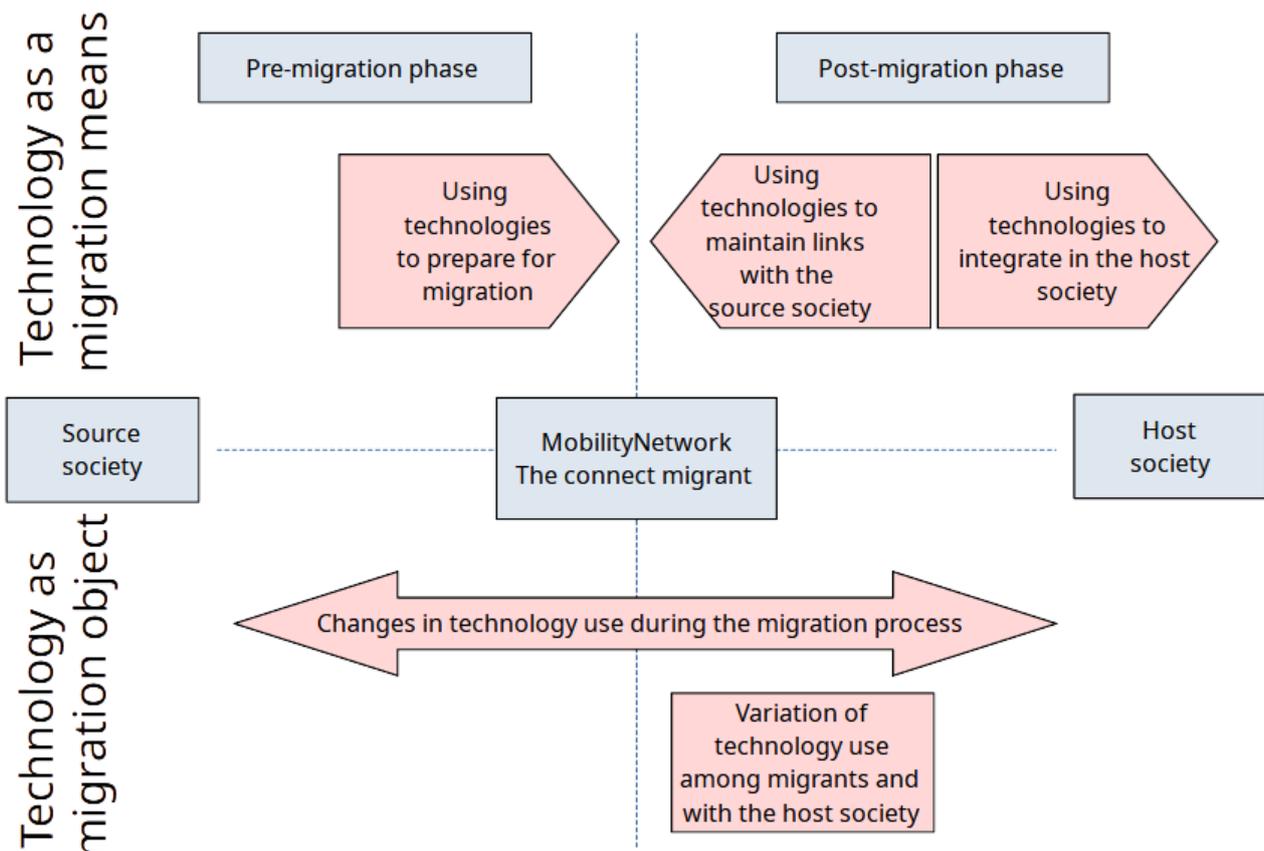
Figure 15 Descriptive frame of research objects in the field of migration and technologies (Collin, Karsenty and Calonne, 2015)

A study, including some of the same authors, concludes that refugees who received computers had several main uses: translation (including formal interaction with the administration). They profit from help from a larger circle, including the family. A minority has sufficient skills for autonomous use.

5.4.9   Adult Learning

Adult learning theories study how adults learn and also how adult learning programs should be designed. Engaging adults to learn is in some aspect informed by motivations to work. Adults learn better if they encounter a variety of meaningful tasks, if they are given autonomy, can complete their work and receive meaningful feedback. Hackman & Oldham /1976)

5.4.10   Workplace Learning

While there are differences between engaging in fablab activities and work, there are shared elements. According to Billet (2001:209), the readiness of the workplace to afford opportunities for individuals to engage in work activities and access direct and indirect support is a key determinant of the quality of learning in workplaces. This readiness can promote individuals' engagement. However, this engagement remains dependent on the degree by which individuals wish to engage purposefully in the workplace. The author then states that "overall, it seems learners afforded the richest opportunities for participation reported the strongest development, and that workplace readiness was central to the quality of experiences."

In Billet's (2013) definition of co-participation as pedagogy of community, "workplaces are not just only venues where individuals merely engage in tasks; they are also a constituted component of individual's thinking, action and learning. They furnish activities, interactions with others, physical tools and symbols that mediate learning, secured through the individual's cognitive and social psychological experience. [...]

Contributions to cognition are distributed across workplaces, but individuals are more than mere internalisers, they are critical participants and appropriators. [...] For the kind of learning required to participate and learn fully at work, individuals need to be richly engaged and shape the practice as well as being shaped themselves (Lave and Wenger, 1991)."

5.4.11 Connectivist Theory

Connectivism (Siemens, 2004) is a more recent theory that attempts to integrate the impact of modern everyday technology on learning. It is closed related to socio-constructivist and situated learning theory and as such does not differ in its explanation of learning mechanisms. It can be used as high-level educational strategy on how learning should or could happen in the modern networked and social environment and as such it can inform teachers and instructional designs for constructivist, situated and authentic learning design practice.

Behaviorism, cognitivism, and constructivism are the three broad learning theories most often utilized in the creation of instructional environments. These theories, however, were developed in a time when learning was not impacted through technology. Over the last twenty years, technology has reorganized how we live, how we communicate, and how we learn. Learning needs and theories that describe learning principles and processes should be reflective of underlying social environments. [...] Connectivism is the integration of principles explored by chaos, network, and complexity and self-organization theories. Learning is a process that occurs within nebulous environments of shifting core elements – not entirely under the control of the individual. Learning (defined as actionable knowledge) can reside outside of ourselves (within an organization or a database), is focused on connecting specialized information sets, and the connections that enable us to learn more are more important than our current state of knowing. (Siemens, 2004)

5.4.12 Community of practice models

Research on communities of practice (Lave & Wenger, 1991) shows that becoming a member of a community entails acquiring a professional identity that implies knowledge creation and sharing activities with group members. Members of a community of practice usually go through a process of initial peripheral participation before becoming a member that understands common goals, language and practice. Developmental processes require that learners first are willing to engage in a new experience and to understand what is expected ("I know"). In a next step ("I can") a learner will be able to learn in a new environment and then gradually become more active. Between each step there are hurdles that must be overcome.

Community of inquiry is a related four component model: Educational (or learning experience) is defined as the interaction of social presence, cognitive presence, teaching presence and an enabling context. Cognitive presence is the extent to which the participants in any particular configuration of a community of inquiry are able to construct meaning through sustained communication. Social presence is the ability of learners to project their personal characteristics into the community of inquiry, thereby presenting themselves as 'real people'. Teaching presence is defined as the design, facilitation, and direction of cognitive and social processes for the purpose of realizing personally meaningful and educational worthwhile learning outcomes.
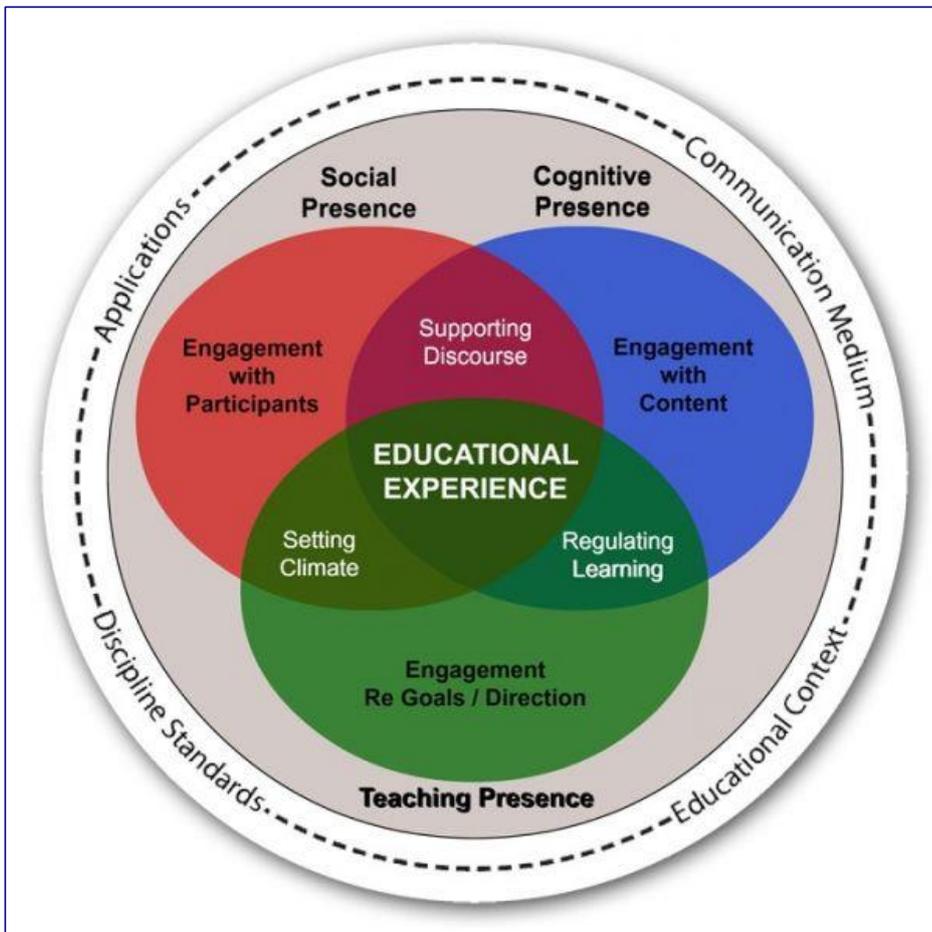
Figure 16: Community of inquiry model, Retrieved from http://www.thecommunityofinquiry.org/coi

5.4.13 Instrumentation

Instrumentation is related to action, i.e., how a technical object is used within an activity and how it affects cognitive schemas.

An activity consists of acting upon an object in order to realize a goal and give concrete form to a motive. Yet the relationship between the subject and the object is not direct. It involves mediation by a third party: the instrument [...]. An instrument cannot be confounded with an artifact. An artifact only becomes an instrument through the subject's activity. In this light, while an instrument is clearly a mediator between the subject and the object, it is also made up of the subject and the artifact. (Béguin & Rabardel, 2000:175)

5.4.14 Five Domains of Adolescent Well-being

The five domains of adolescent well-being that underpin the adolescent well-being framework of Ross et al. (2020) is framework that could be used to formulate evaluation criteria for impact research. As we pointed out before, generalizable and internally valid research that addresses many dimensions requires a huge amount of means. However, meaningful and interesting research can be carried out with relatively simple pre/post survey research that includes a control population, under the condition that validated short scales can be obtained. Multiple full-scale questionnaires simply take too much participant's time to complete (e.g. several hours)

1. **Good health and optimum nutrition**
    1. Physical health and capacities.
    2. Mental health and capacities.
    3. Optimal nutritional status and diet

2. **Connectedness, positive values, and contribution to society**

   1. **Connectedness:** Is part of positive social and cultural networks and has positive, meaningful relationships with others, including family, peers, and, where relevant, teachers and employers.

   2. **Valued** and respected by others and accepted as part of the community.

   3. **Attitudes:** Responsible, caring, and has respect for others. Has a sense of ethics, integrity, and morality.

   4. **Interpersonal skills:** Empathy, friendship skills, and sensitivity.

   5. **Activity:** Socially, culturally, and civically active.

   6. **Change and development:** Equipped to contribute to change and development in their own lives and/or in their communities.

3. **Safety and a supportive environment**

   1. **Safety:** Emotional and physical safety.

   2. **Material conditions** in the physical environment are met.

   3. **Equity:** Treated fairly and have an equal chance in life.

   4. **Equality**: Equal distribution of power, resources, rights, and opportunities for all.

   5. **Nondiscrimination**.

   6. **Privacy**. Non-disclosure of personal information

   7. **Responsive**: Enriching the opportunities available to the adolescent.

4. **Learning, competence, education, skills, and employability**

   1. **Learning**: Has the commitment to, and motivation for, continual learning.

   2. **Education.** Has access until 16, plus informal or formal beyond.

   3. **Resources, life skills, and competencies:** Has the necessary cognitive, social, creative, and emotional resources, skills (life/decision-making) and competencies to thrive, including knowing their rights and how to claim them, and how to plan and make choices.

   4. **Skills:** Acquisition of technical, vocational, business, and creative skills to be able to take advantage of current or future economic, cultural, and social opportunities.

   5. **Employability.** Opportunities for "decent" appropriate jobs

   6. **Confidence** that they can do things well.

5. **Agency and resilience**

   1. **Agency:** Has self-esteem, a sense of agency and of being empowered to make meaningful choices and to influence their social, political, and material environment and has the capacity for self-expression and self-direction appropriate to their evolving capacities and stage of development.

   2. **Identity:** Feels comfortable in their own self and with their identity(s), including their physical, cultural, social, sexual, and gender identity.

   3. **Purpose:** Has a sense of purpose, desire to succeed, and optimism about the future.

   4. **Resilience:** Equipped to handle adversities both now and in the future, in a way that is appropriate to their evolving capacities and stage of development.

   5. **Fulfillment:** Feels that they are fulfilling their potential now and that they will be able to do so in the future.

5.4.15 Design thinking

Design thinking is a concept used in many contexts and it is rather ill-defined. Most often it is used to describe a kind of design methodology. Dorst (1997), distinguishes two paradigms of current design methodology: design seen as a **rational problem solving process** and design considered as a **reflective practice**.
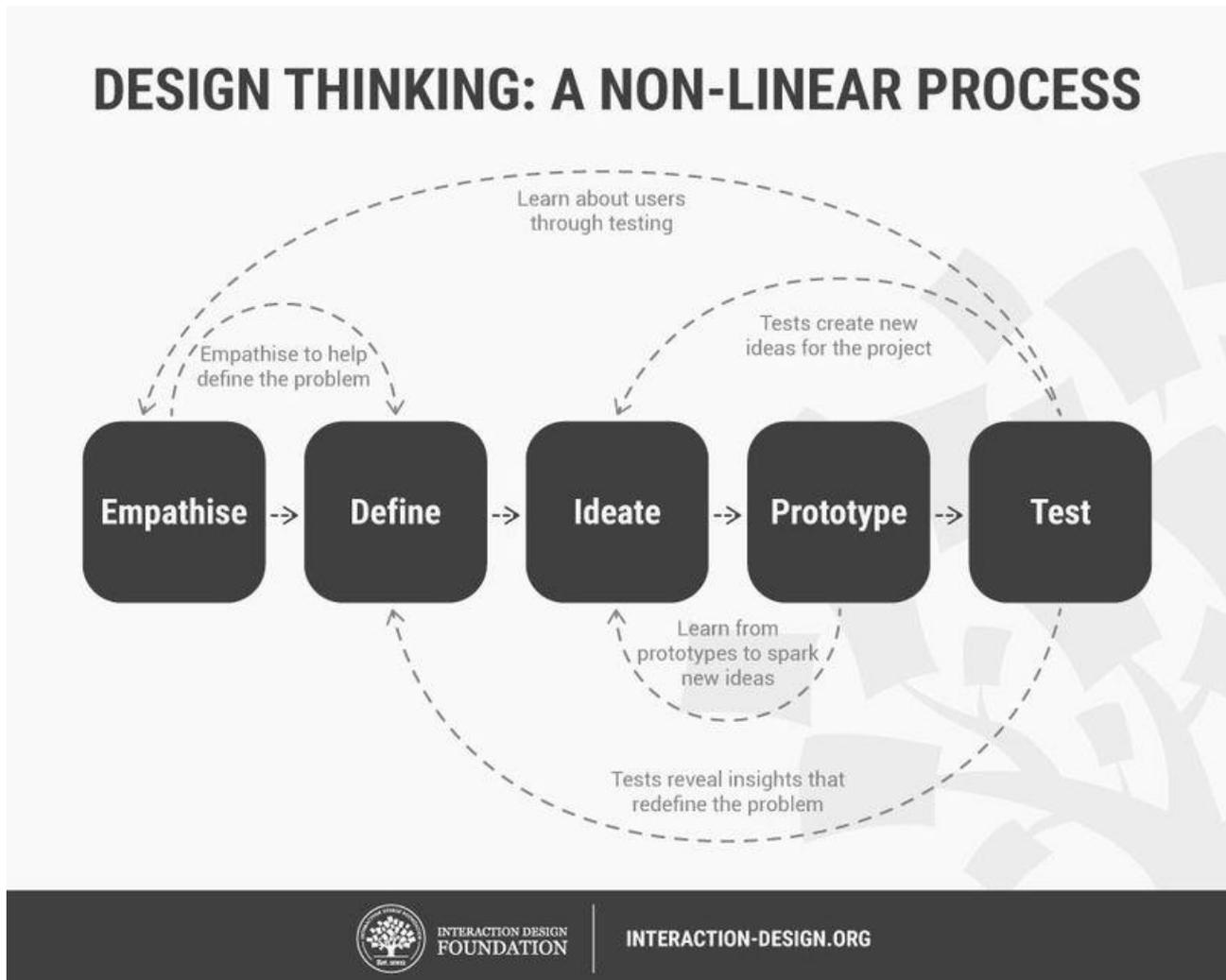
Figure 17 D.School Design Thinking model. Source: interaction-design.org.

Design Thinking is an iterative and non-linear process. This simply means that the design team continuously use their results to review, question and improve their initial assumptions, understandings and results. Results from the final stage of the initial work process inform our understanding of the problem, help us determine the parameters of the problem, enable us to redefine the problem, and, perhaps most importantly, provide us with new insights so we can see any alternative solutions that might not have been available with our previous level of understanding.

5.5 Data Gathering and Analysis Techniques

There exist many types of data gathering techniques. Below a few that are popular in implementation research.

Data gathering

Situation	**Articulation**		
	non-verbal and verbal	**verbal**	
		oral	**written**
informal	participatory observation	Information interview	text analysis, log file analysis, etc.
formal and unstructured	systematic observation	open interviews, semi-structured interviews, thinking aloud protocols, Focus groups, Biographic method	open questionnaires, journals, vignettes, …
formal and structured	Experiment, simulation	standardized interview,	standardized questionnaires, experience sampling log files of structured user interactions,

Below, we summarize the purpose of some of these data gathering techniques.

Document Analysis

Documents can be analyzed using various quantitative and qualitative methods. In the latter case, the same techniques as for semi-structured interviews are used, i.e. codebooks that allow identifying concepts and patterns in a reliable way.

Focus Groups

To elicit controversial and common opinions about a subject.

Semi structured Interviews

To find collect subjective representations of behavior and attitudes with respect to a list of research questions

Field observations

To absorb all sources of information, including the physical settings, language used, interaction patterns. A researcher takes part as a neutral observer and takes field notes. Filming is also an option. Longer "ethnographic" observation allows studying culture, e.g., in a community of practice.

Grids

A technique used in formative evaluation research. Participants and researchers fill in a grid. E.g. Maturity Grid

Participatory Observation

To transform practice, e.g., introduce a new pedagogical model. The researcher participates in the activities and takes notes at the same time.

Repertory grid (or other semantic differential)

To elicit personal constructs, participants are prompted to classify objects with semantic differentials which then allows create "maps" that summarize how objects in a given domain are perceived.

Scenario/story writing

To elicit informal narrative descriptions to understand activity flows.

Surveys

The classic sociology instrument, to understand attitudes but also (subjectively) perceived behaviors. Survey instruments need to be calibrated and it is therefore best to use published scales.

Task observation and thinking aloud

To study cognitive processes, e.g., problem-solving activities

Quantative "objective" data

To observe what people do and create, e.g., log files, statistics (e.g., credits received).

Tests

To study change, usually in a quasi-experimental setting but also in correlation studies, e.g. survey with MCQs and similar, as well as qualitative assessment methods.

5.6   Survey instruments

The exist many published survey instruments that could be suitable for measuring important concepts. However, combining these into single survey studies is not realistic since they the quantity of questions would be much too high. Therefore, we recommend selecting short versions if they exist. Also consider creating and validating your own short version. For illustration purposes, below are few examples of scales:

- CENTRIM (Innovation Capability Reference Model)
- TAM (Technology Acceptance Model)
- SWLS (Satisfaction with life scale)
- Intercultural Sensitivity Scale
- ICAI (Information Competency Assessment Instrument)
- Learning effectiveness (various scales but that should be adapted)
- IMI (Intrinsic Motivation Inventory) or MSLQ (Motivated Strategies for Learning Questionnaire), both need to be adapted
- SDLI (Self-Directed Learning Instrument)

5.7 Data analysis

In this section we shall point to a few less common techniques, e.g. various confirmatory multivariate statistics are not mentioned here.

Thematic analysis

Thematic analysis identifies and categorizes topics that appear in qualitative (text data). (Braun and Clark, 2006). A method that is suitable for novices in qualitative data analysis and that we recommend for light-weight impact studies.

Thematic networks

Thematic networks arrange elements of thematic analysis in the form of connected graphs. (Attride-Stirling, 2001)

Cluster Analysis

Quantitative method allowing to group participants according to multiple criteria (variables). Also allows grouping variables (more robust than traditional factor analysis) or both, i.e. two way-clusters. Cluster analysis allows identifying types of persons or groups of variables that share common features.

5.8 Sampling considerations

Sampling considerations are important at all level of analysis and concern all objects that are examined. Cases:

- In comparative studies, consider studying similar systems that differ with respect to key research variables, i.e. cases that differ only with respect to key independent and dependant variables used in research questions.
- Survey studies (participants across institutions): At least 200 persons, preferably randomly selected.

Within a case:

- Surveys: Sample a maximal variation of participants (random selection of participants for larger N, quotas for small N).
- Interview participants: At least 2-3 persons per role, preferably being different
- Other objects: Sample all categories of data required (activities, processes, events, dates, locations, agents, …)

6 References and bibliography

- Atkinson, R., & Shiffrin, R. (1968). Human memory: A proposed system and its control processes. In K Spence & J Spence (Eds.). The psychology of learning and motivation: Advances in research and theory (Vol. 2). New York: Academic Press.
- Attride-Stirling, J. Thematic networks: an analytic tool for qualitative research. Qualitative Research. 2001; 1(3): 385-405. Available at: https://doi.org/10.1177/146879410100100307
- Béguin, P. & Rabardel, P. (2000). Designing for instrument-mediated activity. Scandinavian Journal of Information Systems 12, 173-191.
- Bell, L., Brown, A., Bull, G., Conly, K., Johnson, L., McAnear, A., Maddux, C., Marks, G., Thompson, A., Schmidt, D., Schrum, L., Smaldino, S., Spector, M., & Sprague, D. (2010). Educational implications of the digital fabrication revolution. TechTrends, 54(5). 2-5. https://doi.org/10.1007/s11528-010-0423-2
- Berry J.W. (1974). Psychological aspects of cultural pluralism. Culture Learning, 2, 17–22.

- Betts, A., & Bloom, L. (2014). Humanitarian Innovation: The State of the Art. Retrieved from www.reliefweb.int
- Billett S., Choy, S. (2013) "Learning through work: emerging perspectives and new challenges", Journal of Workplace Learning, Vol. 25 Iss: 4, pp.264 - 276
- Billett, S. (2001). "Learning through work: workplace affordances and individual engagement", Journal of Workplace Learning, Vol. 13 Iss 5 pp. 209 – 214. http://dx.doi.org/10.1108/EUM0000000005548
- Blikstein, P., & Krannich, D. (2013, June). The makers' movement and FabLabs in education: experiences, technologies, and research. In Proceedings of the 12th international conference on interaction design and children (pp. 613-616). ACM. https://doi.org/10.1145/2485760.2485884
- Braun, V., and Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology 3 (2), 77-101. Retrieved from http://www.tandfonline.com/doi/abs/10.1191/1478088706qp063oa
- Burkhardt, H. et Schoenfeld, A. H. (2003). Improving educational research: Toward a more useful, more influential, and better-funded enterprise. Educational Researcher, 32(9), 3-14
- Bussmann Werner, Klöti Ulrich, Knoepfel Peter. (1997). Einführung in die Politikevaluation, Basel.
- Bussmann, W. (1995). Evaluationen staatlicher Massnahmen erfolgreich begleiten und nutzen. Ein Leitfaden 2. Auflage 1995, Verlag Rüegger AG Chur/Zürich. Für die Veröffentlichung auf dem Internet leicht bearbeitete Auflage. https://www.openegov.admin.ch/dam/bj/de/data/staat/evaluation/materialien/evalmassnahmen-d.pdf.download.pdf/evalmassnahmen-d.pdf
- Bussmann, W., Accompagner et mettre à profit avec succès les évaluations des mesures étatiques : Guide de réflexion. Genève, Georg, 1995
- Chapin, F. S., Knapp, C. N., Brinkman, T. J., Bronen, R., & Cochran, P. (2016). Community-empowered adaptation for self-reliance. Current Opinion in Environmental Sustainability, 19, 67–75. https://doi.org/https://doi.org/10.1016/j.cosust.2015.12.008
- Collin, S., Calonne, O., Lemieux, M.-M., & Michaud, A. H. (2018). Réfugiés syriens et usages numériques pour leur inclusion au canada : le cas de l'initiative #bienvenueauxréfugiés (2017-8) / syrian refugees and digital uses for their inclusion in canada: the case of the #welcomerefugees initiative (2017-8). Retrieved from https://www.researchgate.net/project/Refugies-syriens-et-usages-numeriques-pour-leur-inclusion-au-Canada-le-cas-de-linitiative-BienvenueAuxRefugies-2017-8-Syrian-Refugees-and-Digital-Uses-for-their-Inclusion-in-Canada-The-Case-of-the
- Collin, S., Karsenti, T., & Calonne, O. (2015). Migrants' Use of Technologies: An Overview of Research Objects in the Field. Journal of Technologies and Human Usability, 10(3–4), 15–29. https://doi.org/10.18848/2381-9227/cgp/v10i3-4/56424
- Conner, M. L., & Clawson, J. G. (2004). Creating a learning culture: strategy, technology, and practice. Cambridge University Press.
- Cook, Thomas, K. and Campbell, Donald T. (1979). Quasi-Experimentation: Design and Analysis Issues for Field Settings, Houghton Mifflin Company, ISBN-10 0395307902
- Corsini, L., & Moultrie, J. (2020). Humanitarian makerspaces in crisis-affected communities. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing: AIEDAM*, *34*(3), 374–386. https://doi.org/10.1017/S0890060420000098
- Corsini, L., Aranda-Jan, C. B., & Moultrie, J. (2019). Using digital fabrication tools to provide humanitarian and development aid in low-resource settings. *Technology in Society*, *58*. https://doi.org/10.1016/j.techsoc.2019.02.003
- Corsini, L., Aranda-Jan, C. B., & Moultrie, J. (2019). Using digital fabrication tools to provide humanitarian and development aid in low-resource settings. *Technology in Society*, *58*. https://doi.org/10.1016/j.techsoc.2019.02.003
- Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: a comparison of two theoretical models. Management science, 35(8), 982-1003.
- Deci, E. L. (1972). Intrinsic motivation, extrinsic reinforcement, and inequity. Journal of Personality and Social Psychology, 22(1), 113–120. https://doi.org/10.1037/h0032355

- Deci, E. L., Koestner, R., & Ryan, R. M. (2001, June 30). Extrinsic rewards and intrinsic motivation in education: Reconsidered once again. Review of Educational Research. American Educational Research Association. https://doi.org/10.3102/00346543071001001
- Dittert, N., & Katterfeldt, E.-S. (2018). Diversity in Digital Fabrication: Programming Personally Meaningful Textile Imprints. FabLearn Europe'18: Proceedings of the Conference on Creativity and Making in Education. https://doi.org/10.1145/3213818.3219812
- Dorst, K. (1997). Describing design: a comparison of paradigms. Technische Universiteit Delft. http://resolver.tudelft.nl/uuid:2055acc5-bdc9-4e03-a24c-332ea4f454d2
- Duckworth, A. (2016). Grit: The power of passion and perseverance. New York: Scribner.
- Engeström, Y., Virkkunen, J., Helle, M., Pihlaja, J. & Poikela, R. (1996). The Change laboratory as a tool for transforming work. Lifelong Learning in Europe, 1(2), 10
- Engeström, Y (2001). Expansive Learning at Work: toward an activity theoretical reconceptualization. Journal of Education and Work, Vol. 14, No. 1, 2001
- Francis, D. L. (2005). A Reference Model of Innovation Capability and Implications for Organisational Development The Agile Organisation View project. Retrieved from https://www.researchgate.net/publication/28550949
- Freire, P. (1993). Pedagogy ofthe oppressed: New revised 20th anniversary edition. New York: Continuum.
- Gahagan, P. M., & Calvert, P. J. (2020). Evaluating a Public Library Makerspace. Public Library Quarterly, 39(4), 320–345. https://doi.org/10.1080/01616846.2019.1662756
- Gaggioli, A., Riva, G., Peters, D., & Calvo, R. A. (2017). Positive technology, computing, and design: shaping a future in which technology promotes psychological well-being. In Emotions and affect in human factors and human-computer interaction (pp. 477-502). Academic Press. http://dx.doi.org/10.1016/B978-0-12-801851-4.00018-5
- Gantert, T. M., Fredrich, V., Bouncken, R. B., & Kraus, S. (2022). The moral foundations of makerspaces as unconventional sources of innovation: A study of narratives and performance. *Journal of Business Research*, *139*, 1564–1574. https://doi.org/10.1016/J.JBUSRES.2021.10.076
- Given, L. (2012). The SAGE Encyclopedia of Qualitative Research Methods. (L. M. Given, Ed.), The SAGE Encyclopedia of Qualitative Research Methods. London: Sage Publications. https://doi.org/10.4135/9781412963909
- Hackman, J. R. & G. R. Oldham (1976). Motivation through the design of work: Test of a theory, Organizational Behavior and Human Performance 16, p. 250.
- Hammer, Mitchell R. (2015). The Developmental paradigm for intercultural competence research, International Journal of Intercultural Relations, Volume 48, September 2015, Pages 12-13, ISSN 0147-1767, http://dx.doi.org/10.1016/j.ijintrel.2015.03.004.
- Hammer, Mitchell R. ; Milton J. Bennett, Richard Wiseman, Measuring intercultural sensitivity: The intercultural development inventory (2003). International Journal of Intercultural Relations, Volume 27, Issue 4, July 2003, Pages 421-443, ISSN 0147-1767, http://dx.doi.org/10.1016/S0147-1767(03)00032-4.
- Hector, P., & Botero, A. (2021). Generative repair: everyday infrastructuring between DIY citizen initiatives and institutional arrangements. CoDesign. https://doi.org/10.1080/15710882.2021.1912778
- Heutte, J., Fenouillet, F., Martin-Krumm, C., Boniwell, I., & Csikszentmihalyi, M. (2016). *Proposal for a conceptual evolution of the flow in education (EduFlow) model.* 8th European Conference on Positive Psychology (ECPP 2016), Angers, France. http://refa.univ-lille.fr/news/eduflow2-heutte-heutte-fenouillet-martin-krumm-boniwell-csikszentmihalyi-2016
- Huberman, A. M. (1973). Understanding Change in Education: An Introduction. Experiments and Innovations in Education No. 4. The Unesco Press.
- Järvinnen, (2004), On research methods, Tampere: Opinpajan Kirja.
- Khandker, S., B. Koolwal, G., & Samad, H. (2009). Handbook on Impact Evaluation. Handbook on Impact Evaluation. The World Bank. https://doi.org/10.1596/978-0-8213-8028-4

- Kraus, S., Bouncken, R. B., Görmar, L., González-Serrano, M. H., & Calabuig, F. (2022). Coworking spaces and makerspaces: Mapping the state of research. *Journal of Innovation and Knowledge*, *7*(1). https://doi.org/10.1016/j.jik.2022.100161
- Kuhn, T.S. (1996). *The Structure of Scientific Revolutions.* Chicago: University of Chicago Press.
- Leung, K. S. Ang, M.L. Tan (2014). Intercultural competence, Annual Review of Organizational Psychology and Organizational Behavior, 1 (2014), pp. 489–519 http://dx.doi.org/10.1146/annurev-orgpsych-031413-091229
- Maier, A. M., Moultrie, J., & Clarkson, P. J. (2012). Assessing organizational capabilities: Reviewing and guiding the development of maturity grids. *IEEE Transactions on Engineering Management*, *59*(1), 138–159. https://doi.org/10.1109/TEM.2010.2077289
- Malone, M. R., & Lepper, M. R. (1987). Making learning fun: A Taxonomy of Intrinsic Motivations for Learning. In R. E. Snow & M. J. Farr (Series Eds.), R. E. Snow & J. F. Marshall Vol. Eds.), Aptitude, learning, and instruction, vol. 4: Conative and affective process analyses (pp. 223–253). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Mayer, R. E. (2001). Multimedia learning. New York: Cambridge University Press.
- Mc Kenney, S. & Reeves, T. C. (2014) Educational design research. Dans Spector, J. M., Merrill, D., Elen, J. et Bishop, M. J. (dir.), *Handbook of research on educational communications and technology* (pp. 131-140), 4th edition, Springer Science, New York.
- Moore, G. (1991). Crossing the Chasm. New York: Harper Business.
- Myers, D. G., & DeWall, C. N. (2020). Psychology (13th ed), Worth Publishers.
- Nagi, Y., Sender, H., Orcutt, M., Fouad, F., Burgess, R. A., & Devakumar, D. (2021). Resilience as a Communal Concept: Understanding adolescent resilience in the context of the Syrian refugee crisis in Bar Elias, Lebanon. Journal of Migration and Health, 100046. https://doi.org/10.1016/j.jmh.2021.100046
- Pass, Fred; Alexander Renkl and John Sweller (2003). Cognitive Load Theory and Instructional Design: Recent Developments, *Educational Psychologist*, 38(1), 1-4.
- Peters, D. H., Adam, T., Alonge, O., Agyepong, I. A., & Tran, N. (2013). Implementation research: what it is and how to do it. *Bmj*, *347*.
- Poll, R. 2012. Can we quantify the library's influence? Creating an ISO standard for impact assessment. Performance Measurement and Metrics 13 (2):121–30. doi:10.1108/14678041211241332.
- Reeves, T. C. (2000). Enhancing the worth of instructional technology research through "design experiments" and other development research strategies. *International perspectives on instructional technology research for the 21st century*, *27*, 1-15.
- Riege, A. M. 2003. Validity and reliability tests in case study research: A literature review with "hands-on" applications for each research phase. Qualitative Market Research: An International Journal 6 (2):75–86. doi:10.1108/13522750310470055
- Ross, D. A., Hinton, R., Melles-Brewer, M., Engel, D., Zeck, W., Fagan, L., ... & Mohan, A. (2020). Adolescent well-being: a definition and conceptual framework. Journal of Adolescent Health, 67(4), 472-476. DOI:https://doi.org/10.1016/j.jadohealth.2020.06.042
- Sam, David L. and John W. Berry, Acculturation, When Individuals and Groups of Different Cultural Backgrounds Meet, *Perspectives on Psychological Science*, July 2010 vol. 5 no. 4 472-481
- Schön D (1983) The reflective practitioner. Basic Books: New York
- Seligman, M. E., & Csikszentmihalyi, M. (2000). Positive psychology: An introduction (Vol. 55, No. 1, p. 5). American Psychological Association.
- Siemens, G. (2004). Connectivism: A learning theory for the digital age. International Journal of Instructional Technology and Distance Learning. Retrieved from http://www.itdl.org/Journal/Jan_05/article01.htm.
- Stickel, O., Hornung, D., Aal, K., Rohde, M., & Wulf, V. (2015). 3D Printing with Marginalized Children—An Exploration in a Palestinian Refugee Camp. In ECSCW 2015: Proceedings of the 14th European Conference on Computer Supported Cooperative Work, 19-23 September 2015, Oslo,

Norway (pp. 83–102). Springer International Publishing. https://doi.org/10.1007/978-3-319-20499-4_5

- Stokes, D. (1997). *Pasteur's Quadrant: Basic Science and Technological Innovation*. Virginia: Brookings Institution Press.
- Tashakkori, A. et Teddlie, C. (2009). *Handbook of mixed methods in social and behavioral research*. Thousand Oaks: Sage.
- Streatfield, D. , and S.Markless . 2009. What is impact assessment and why is it important? Performance Measurement and Metrics 10 (2):134 –41. doi:10.1108/14678040911005473
- Town, S. J. , and M.Kyrillidou . 2013. Developing a values scorecard. Performance Measurement and Metrics 14 (1):7–16. doi:10.1108/14678041311316095.
- de Vries, M. J., Fletcher, S., Kruse, S., Labudde, P., Lang, M., Mammes, I., ... & Winterbottom, M. (2020). *The Impact of Technology Education: International Insights* (Vol. 3). Waxmann Verlag.
- Ward, Colleen, and Arzu Rana-Deuba. "Acculturation and adaptation revisited." Journal of cross-cultural psychology 30, no. 4 (1999): 422-442.