# Building Theory of Digital Fabrication Laboratories in the Field of Information System using Grounded Theory Approach

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**Abstract**

*This study illustrates a grounded theory approach to build the theory of digital fabrication laboratories in the field of information systems. This approach is chosen based on the theory-building process, where data is drawn from the thoughts, experiences, and views of the respondents. This study involved 5 (five) respondents who came from practitioners and lecturers in the field of information systems. Data collection results were analyzed through three stages, namely open coding, axial coding, and selective coding. Based on these stages, the definition of digital fabrication laboratories in the field of information systems is a medium for exchanging knowledge between experts and learners which has components of exchange techniques/methods knowledge, technology, motivation, features, and themes in the field of information systems that are part of the conversion process knowledge on the SECI framework. Due to time constraints, this study only uses data from practitioners. This media can be designed and implemented by educational organizations in the field of information systems so as to increase the effectiveness and efficiency of the knowledge conversion process.*

***Keywords:*** Digital fabrication laboratories, Information System, Grounded theory, Knowledge

## 1. INTRODUCTION

The COVID 19 pandemic has changed the mechanism of the education and training process in Indonesia. Many teachers, lecturers, and students have difficulty adapting to find the right way of learning [ls5]. Nonaka (2001), Polanyi (1967), Polanyi (1969) in (Rolf, 2004) ) revealed that in the knowledge exchange process, we recognize two types of knowledge, namely tacit and explicit knowledge. Explicit knowledge is a form of formal knowledge that can be shared, whereas tacit knowledge is the opposite; informal knowledge that is difficult to capture and codify (Rolf, 2004). (Cooper, 2017) explained that explicit knowledge is a form of knowledge that is readily available and easy to distribute. In contrast, tacit knowledge, according to Grant in (Yusof et al., 2017) explained that tacit knowledge needs a mechanism to be translated into explicit knowledge; this mechanism is the key to the success



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of the knowledge transfer process. Based on these two types of knowledge (Nonaka & Takeuchi, 1997) proposed four knowledge conversion processes, namely socialization, externalization, combination, and internalization. In addition to the models of (Nonaka & Takeuchi, 1997), there are also other models, namely the (Kaur, 2015) ) model, Botha model (Ceptureanu, 2015), and the matrix model (Luo et al., 2016) .

The successful mastery of knowledge requires motivation from sources, namely experts and recipients, namely learners (Gupta & Govindarajan, 2016) (Su et al., 2020), because the knowledge transfer process requires commitment from both parties regarding resources, time, attention, and effort (Chen et al., 2014). Encouragement to the experts is an essential factor in this knowledge transfer process. Experts' behavior regarding methods for storing their explicit knowledge is also a concern to master knowledge successfully. The exchange of knowledge that usually occurs in the teaching and learning process in class, workshop activities, training, etc. requires a medium of meeting between knowledge owners and learners. Seeing the conditions of the COVID 19 pandemic, of course, the effectiveness and efficiency of the knowledge conversion process become a problem[ls6]. Therefore, it is necessary to prepare the right media so that the knowledge conversion process becomes more effective and efficient . (Maravilhas & Martins, 2018) mentions that the media used for knowledge conversion that enables successful mastery of knowledge and encourages learners to be creative to develop a product, as well as assistance from experts who help overcome the difficulties of learners in completing their projects, are called fabrication laboratories (Maravilhas & Martins, 2018). According to the Encyclopedia Britannica (2011) in (Celani, 2012), in the late 1990s, there was an architectural school that had a science laboratory that introduced prototyping, which was supported by computer technology, which was then known as digital fabrication laboratories. Meanwhile (Angrisani et al., 2020) revealed that there are fab learn labs launched by Stanford University in 2008, which are used for the development of educational experiences of constructionism and critical pedagogy.

During the COVID 19 pandemic, many companies develop strategies to improve business through ICT in which there is a field of information systems that contributes to the process. Based on the need for the right knowledge conversion process and the contribution of the information system filed during the COVID 19 pandemic, this study aims to find out the views regarding the knowledge conversion media known as digital fabrication laboratories in the information systems field. Views related to the media can provide a clear description of the appropriate knowledge conversion media in the field of information systems, so that experts and learners can collaborate with each other in order to achieve complete knowledge[ls8].

## 2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

### 2.1 Tacit and Explicit Knowledge

The knowledge conversion process requires proper codification. According to (Dalkir, 2013) (Dagenais et al., 2020), complete knowledge includes explicit knowledge that can be directly codified, articulated, written, and tacit knowledge. Lemire, Souffez , & Laurendeau, (2012) in (Dagenais et al., 2020) clarify that explicit knowledge is more about information resulting from scientific research. In contrast, tacit knowledge is more about knowledge from professionals who have practical experience that is still stored in the head of these professionals. The process of codifying tacit and explicit knowledge and the conversion process involves organizing (Dalkir, 2013) (Nonaka & Toyama, 2002). The process of capturing knowledge from professionals or practitioners by students is sometimes complicated, many practitioners find it difficult to transfer their tacit knowledge into explicit knowledge (Dagenais, 2010). In addition, the character of tacit knowledge that is formed



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from interactions between individuals makes it difficult to understand (Gomez, 1996). Tacit knowledge becomes an individual's wealth that cannot be quickly released (El-Den & Sriratanaviriyakul, 2019). Therefore in creating an effective media for knowledge conversion, it is necessary to pay attention to things that encourage experts to share knowledge. Explicit knowledge can be recovered because it can be communicated, processed, transmitted, and stored relatively easily, whereas tacit knowledge is, however, only known by individuals and is difficult to know or transfer to other individuals because actions, attitudes, commitments, emotions, and behavior are complicated to be delivered in the form of language, and usually, tacit knowledge cannot be separated from the environment, because the environment provides knowledge with meaning (Canonico et al., 2020).

## 2.2 SECI Model

Analysis of knowledge creation using the socialization, externalization, combination, and internalization (SECI) framework by (Nonaka & Takeuchi, 1996) provides a fundamental model for analyzing knowledge creation practices (Canonico et al., 2020). According to (Nonaka & Takeuchi, 1996), the process of knowledge creation and transfer depends on the interaction between tacit knowledge & explicit knowledge, which can be logged as "knowledge conversion". The SECI Model proposes four distinct forms of interaction that lead to forms of knowledge conversion. Four knowledge conversion models (Nonaka et al., 2000) (Canonico et al., 2020) :

- Socialization is the creation of new tacit knowledge from other people obtained from social interactions. An example is sharing experiences through doing activities together.
- Externalization allows the conversion of tacit knowledge into an explicit form; through this process, tacit knowledge is expressed and translated into forms such as concepts, hypotheses, diagrams, models, or prototypes so that it can be understood by others.
- Combination is the creation of new explicit knowledge by combining and synthesizing existing explicit knowledge. Knowledge is exchanged through media such as documents, meetings, or communication networks.
- Internalization is the explicit conversion of organizational knowledge into tacit knowledge at the individual and group levels (Vaccaro et al., 2009).

## 2.3 Digital Fabrication Laboratories

Digital fabrication laboratories first appeared in architectural schools, the first to begin with the use of science laboratories as learning media in architectural schools (Celani, 2012). According to the Encyclopedia Britannica (2011) in (Celani, 2012), science laboratories can be defined as a place where scientific research and development are analyzed using a large number of instruments and procedures to study, systematize, or measure objects of their concern. Procedures that often occur are sampling, pretreatment, treatment, measurement, calculation, and results presentation. (Celani, 2012) explained that science laboratories in architectural schools are used to demonstrate physical concepts in architectural applications and scientific studies of the design process. (Celani, 2012) noted that since the late 1990s, several schools began to introduce rapid prototyping and computer-controlled machines, which were later called digital fabrication laboratories. This space makes it increasingly possible to use rapid prototyping tools for physical models of digital information. (Lyle D. & Albert J, 2005) defined three types of engineering laboratories with different objectives, namely research, development, and education. According to them, research laboratories are used to seek broader generalizable and systematic knowledge, thereby contributing to the



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field's overall knowledge. In research projects, the use of digital fabrication laboratories is often combined with the use of science laboratory equipment. Meanwhile, the purpose of the development laboratory is to obtain experimental data as a professional guide in designing and developing products. This type of laboratory can also collect specific performance measurements to determine whether a design is performing as intended. In comparison, the purpose of an instructional laboratory is defined through learning objectives. Looking at the three types of laboratories based on their purpose, digital fabrication laboratories can function to fulfill these three types of laboratories.

### 2.4 Grounded Theory

Grounded theory is a form of qualitative research developed by Glaser and Strauss (1967) for the purpose of building data-based theory, which enables us to identify general concepts, develop theoretical explanations that go beyond what is known, and offer new insights into various experiences and phenomena. (Corbin & Strauss, 2015). In grounded theory, data is collected in various ways. The types most often collected are interviews and observations, but the data collection of grounded theory is not limited to types of videos, journals, diaries, pictures, etc. (Corbin & Strauss, 2015). The process of a grounded theory begins with the transcribed word, then a memo is written, and open coding is carried out. Categories emerge from codes, topics and ultimately generate explanatory theories or models. The goal of grounded theory is to reach at least level three of conceptual analysis (Maseleno et al., 2019). The first level is data collection. The second is categorizing. The third level is finding the core categories that organize other categories, where the higher level can be called formal theory (Espriella & Restrepo, 2020). Coding is an essential part of the process, which involves reading files and identifying topics, classes, and categories to identify important subtopics (Espriella & Restrepo, 2020). Encoding can involve the following stages (Espriella & Restrepo, 2020) :

- Open coding: looking for conceptual categories in data.
- Axial coding: the goal is to connect categories.
- Selective coding: defining relationships and finding core categories.

Quality in qualitative methods can be handled by the following criteria (Lincoln et al., 1985) :

- Credibility: the correctness of the findings through the research respondent or interviewee's perspective and the researcher's context.
- Transferability: the extent to which findings can be transferred to other contexts
- Dependency: the extent to which the study would produce similar and consistent findings if carried out as described.
- Confirmation: evidence corroborating the findings from the study's subject and context (Devers, 1999).

According to Glaser and Strauss (1967), the quality of grounded theory lies in adaptability, work, relevance, and modifiability. For Strauss and Corbin (1990), there are two sets of criteria, namely the research process and the empirical basis of the findings. According to (Dunn et al., 2017), strategies to build trust in grounded theory are as follows:

Table 1.1 Trust building strategies

| Elements of Trust | Strategies |
|---|---|
| Credibility | Use of interview guides, open minded |



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| | |
|---|---|
| Dependency | Triangulation |
| Transfreability | Identify specific cases and compare negative cases |
| Confirmation | Awareness from researchers |

Source : (Dunn et al., 2017)

## 3. RESEARCH METHODOLOGY

In this study, researchers used a grounded theory method to perform theoretical analysis (Zhu et al., 2020). The grounded theory allows substantial data and research insights from experts in the field of information systems to be considered to explain the mechanisms underlying digital fabrication in the field of information systems, therefore grounded theory is suitable for the formation of a theoretical framework. When using grounded theory in the research process, the interviewee is considered. At the beginning of the study, researchers selected experts in the field of information systems by categories, namely information systems practitioners and permanent lecturers in the information systems study program. When using grounded theory in the research process, researchers use detailed and in-depth semi-structured and open interview material. In this study, researchers conducted in-depth interviews with five subjects and explored the interviews' contents in depth. In addition, in sampling, researchers used non-probability sampling techniques with purposive sampling techniques with the results of respondents who have experience in the field of information systems. Finally, in this study, there were three respondents from practitioners in the field of information systems and two respondents from lecturers of information systems study program who had side jobs as practitioners in the field of information systems.

In this study, information was obtained from respondents through detailed interviews conducted using semi-structured and open-ended questions with about 30 minutes each. The contents of the interview are focused on the experience of knowledge transfer techniques from experts to learners, the motivation of the experts to transfer knowledge, explore technologies that have been used as media for knowledge transfer, the characteristics of appropriate knowledge transfer media, and themes in the field of information systems.

Interview notes were analyzed using the grounded theory method with the following steps:

- Open coding was carried out by sequencing the interview transcript and extracting key phrases that were in accordance with the purpose of the interview questions.
- Axial coding is done by comparing keywords or codes into different categories. Determine the relationship between categories (selective coding)
- The formation of the theory.

## 4. RESULTS AND DISCUSSIONS

The grounded theory method is the right research design to get a theory that explains digital fabrication laboratories in the field of information systems built from practitioners and lecturers' thoughts, experiences, and lecturers in the field of information systems. The interview data collection results were transcribed into a document that was then carried out in an open coding process. The results of the open coding process can be illustrated as follows:



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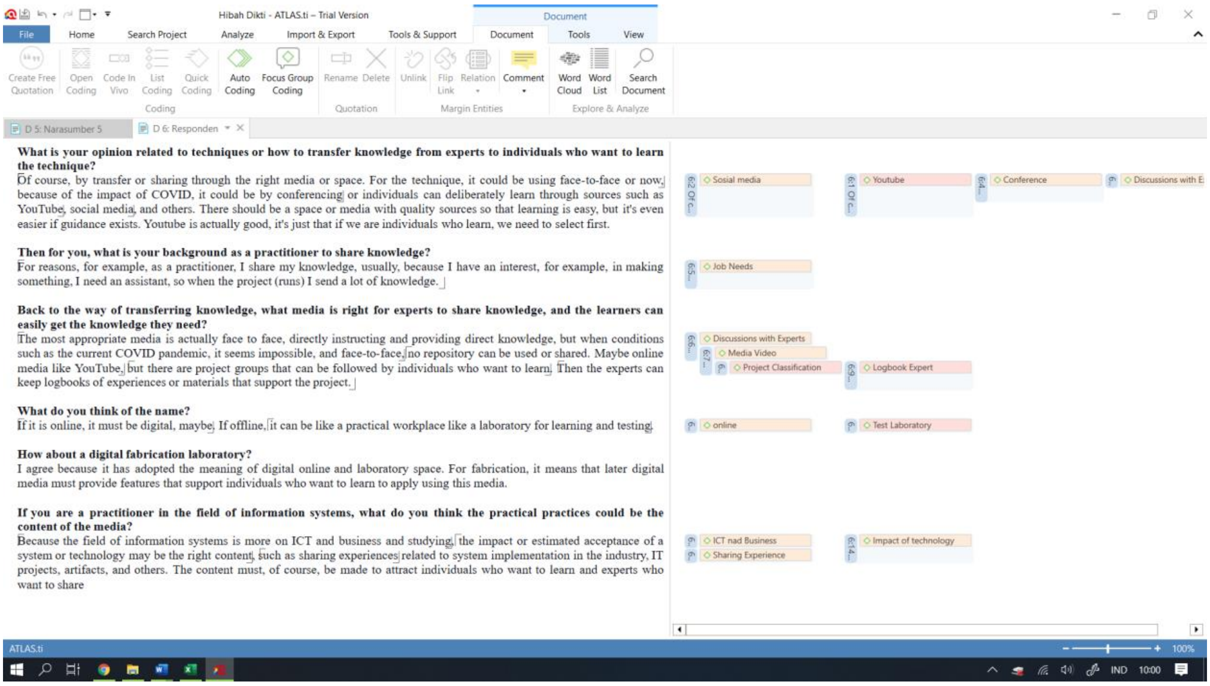


Figure1. Illustration of Open Coding

In the open coding stage, the researcher reads the transcript and marks the information that stands out, which is then categorized based on the segment. These categories are codes in the form of categories that are widely discussed by respondents; in this case, the thoughts, experiences, and views of the respondent. After the researcher did open coding, the researcher did axial coding, which was the mapping stage of codes that explained phenomena centrally. In this study, 5 (five) mappings were obtained, namely the mapping of the knowledge transfer method, the motivation of the experts in sharing knowledge, the technology used by the experts in sharing knowledge, the features expected by the experts, and the themes in the field of information systems. The results of axial coding can be seen in the pictures below:

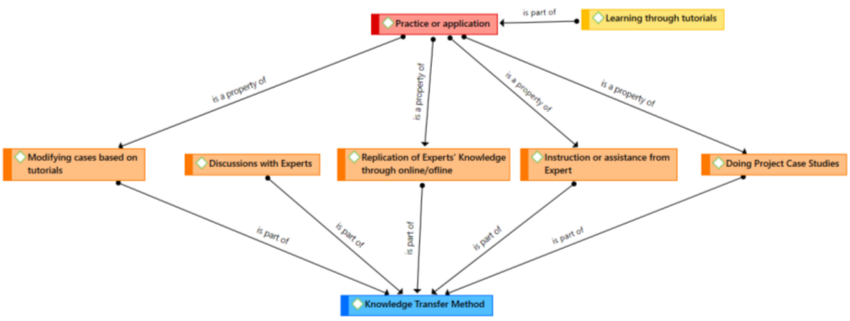


Figure 2. Axial Coding for knowledge transfer method category

In the axial coding of "knowledge transfer method" category, information is obtained that there are several techniques that are most appropriate for transferring knowledge from experts to learners is through discussions with experts, if seen from the knowledge conversion framework, this is a tacit to tacit conversion process (socialization); namely, knowledge moves through individual interaction with individuals (Nonaka et al., 2000) (Canonico et al., 2020). The next technique is the replication of experts' knowledge, expert instruction and mentoring, conducting case studies in this case projects, and modifying cases through



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tutorials. These techniques are included in the category of practice or application where knowledge is obtained from interaction or explicit knowledge (Dagenais et al., 2020), namely tutorials, guidance documents, etc.

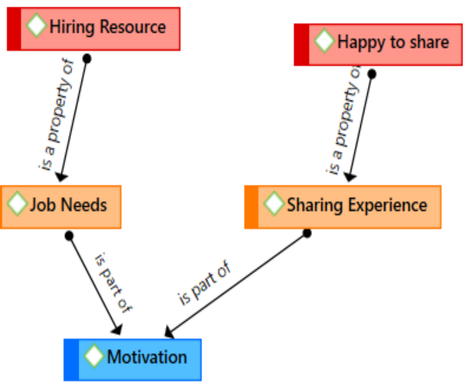


Figure 3. Axial Coding for Motivation Category

Axial coding of experts' motivation category in sharing their knowledge obtained several reasons, including job requirements. Most experts do over the transfer of knowledge when they get a lucrative job and need an assistant who automatically shares knowledge. In addition to the reasons for the need for work, it turns out that various categories make experts share knowledge.

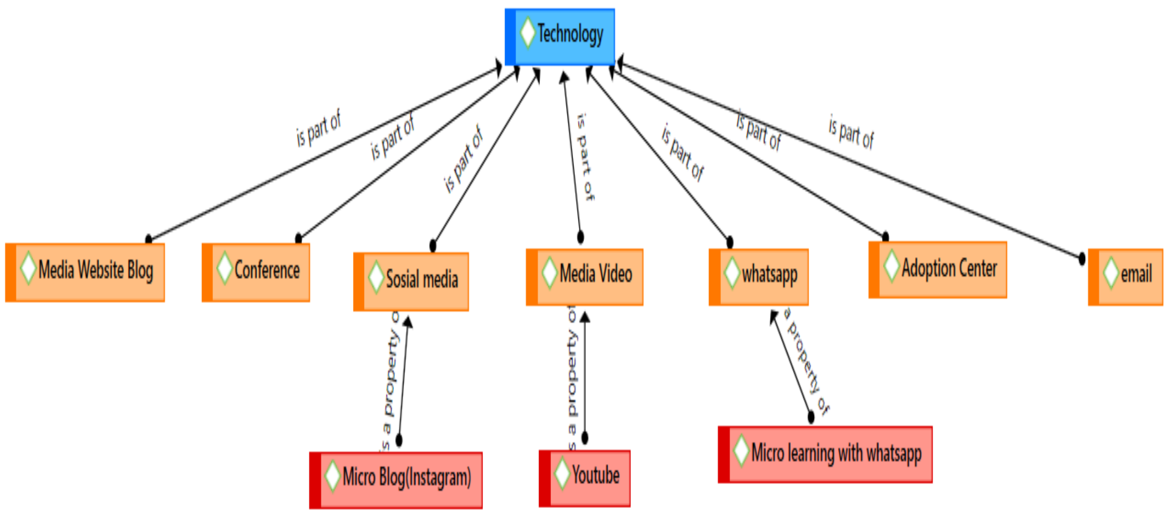


Figure 4. Axial Coding for Technology Category

Axial coding of the technology category describes some technology or media transfer or knowledge transfer used by experts in the transfer process or knowledge transfer. The categories that are part of technology are conference, social media, WhatsApp, email, blog, and youtube. This technology category can refer to features required in digital fabrication laboratories.



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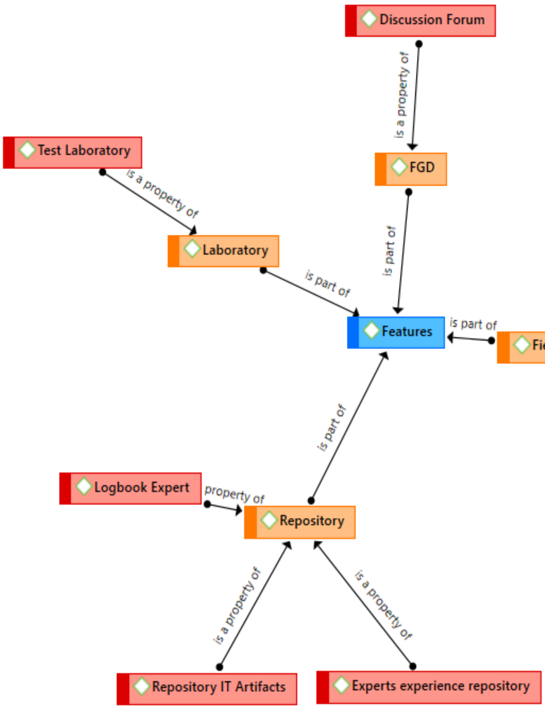


Figure 5. Axial Coding for Fiture Category

Axial coding of the feature category describes some of the features needed in the transfer media for expert knowledge transfer to learners. These features consist of FGD (Focus group discussion), repositories, virtual laboratories, and field classifications. This repository Feature is a repository for IT artifacts, experiences, logbooks from experts.

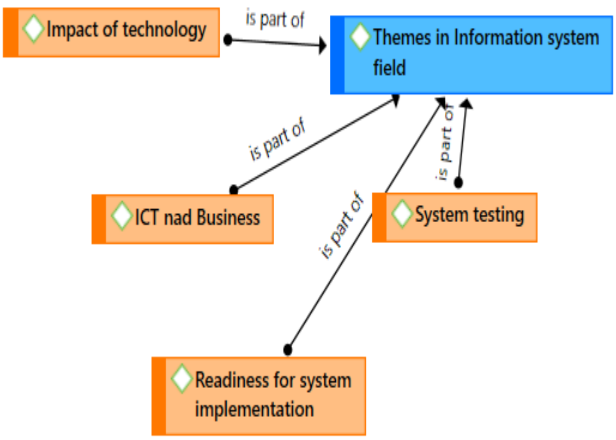


Figure 6. Axial Coding for categories - Information systems field theme

The axial coding of the information system theme category describes the theme of the information systems field. From the results of the centralized category mapping, the researcher connects these categories and constructs the relationship into a category link that becomes the foundation for the definition of digital fabrication laboratories in information systems. The following is an overview of selective coding that explains the contents of digital fabrication laboratories in the field of information systems.



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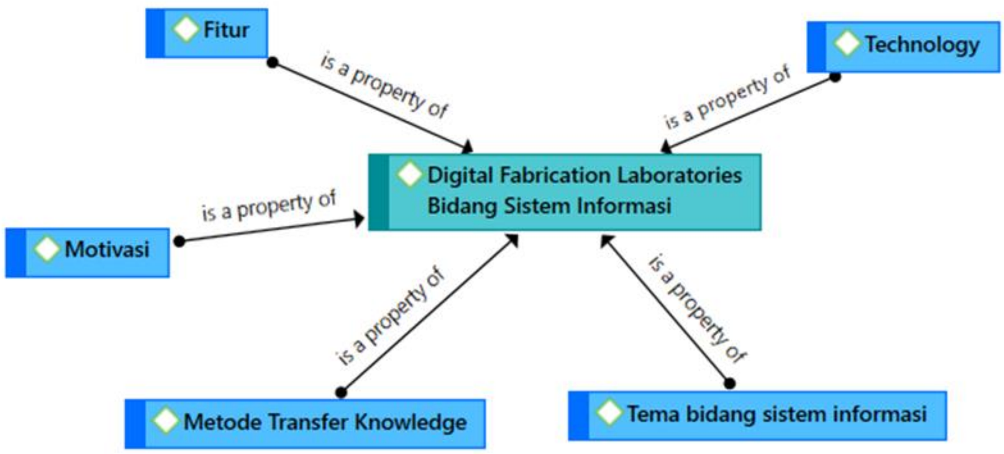


Figure 7. Selective Coding

Based on the mapping of axial coding, it can be connected to define digital fabrication laboratories in the field of information systems.

**Digital Fabrication Laboratories in Information Systems Field**

Knowledge exchange requires the right media, as well as thruster that can trigger knowledge owners to be able to share. Digital fabrication laboratories in the field of information systems are media that can be used by knowledge owners in the knowledge transfer process as well as learners who are ready to receive knowledge from these experts. In building digital fabrication laboratories in the field of information systems, several properties are needed, namely the right knowledge transfer method, a technology that supports the knowledge transfer method, motivation as a driving force for experts and individuals who learn to exchange knowledge, the right features facilitate experts and individuals who learn to exchange knowledge and themes representing the fields of the digital fabrication laboratories.

In building digital fabrication laboratories, technology conferencing applications, social media, blogs, YouTube, and texting applications such as WhatsApp can be used, depending on the experts and the learners' comfort. In choosing the technology, it is necessary to pay attention to the methods or techniques of transfer knowledge required by experts and learners. Looking at the technology and techniques that are part of the digital fabrication laboratories, processes that might occur, including:

- Experts store their experiences (tacit to explicit knowledge) in the form of notes, work/project/research results, video tutorials, other records that can be uploaded in the feature of digital fabrication laboratories repository in the information systems field.
- Learners download explicit knowledge experts and internalize it into a practice form so that it becomes tacit knowledge for them.
- Learners receive assistance from experts through FGD facilities so that there is a conversion from tacit to tacit (socialization). In addition, through this FGD, learners can convert the tacit knowledge of their learning outcomes into explicit knowledge when uploading the results of the trials conducted so that the expert can provide comments in the form of instructions that can provide direction to the learners.



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## 5. CONCLUSION

The construction of the definition of digital fabrication laboratories in the field of information systems through the grounded theory method in several stages, namely, takes data source-open coding, axial coding, and selective coding. Based on these stages, digital fabrication laboratories in the field of information systems can be defined as a medium for exchanging knowledge in which there are components of technology, motivation, knowledge exchange methods/techniques, features, and themes in the field of information systems. In the digital fabrication laboratories in information systems, there is a knowledge conversion process that reflects the SECI framework (Nonaka & Takeuchi, 1996). Educational organizations in information systems can build digital fabrication laboratories in the field of information systems by paying attention to the components and critical success factors reflected in the motivation component. Subsequent research carried out strategic planning in building digital fabrication laboratories in this information systems field.

## LIMITATION AND STUDY FORWARD

Due to time constraints, this study only uses data from practitioners in information system field. Further research can be continued with the preparation of a digital fabrication laboratories strategy plan in the field of information systems

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