Can evaluation studies benefit from triangulation? A case study

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Summary *Background*: Information and communication technologies (ICTs) are increasingly being used in health care. Rigorous evaluations of ICT applications during both introduction and routine use are of great importance for decision makers and users. Within evaluation research, two main (and often rather distinct) traditions can be found: the objectivistic and the subjectivistic tradition. *Methods*: The theory of triangulation deals with the integration of methods and approaches as to conduct better evaluation studies. In evaluation research, triangulation in general means the multiple employment of various sources of data, observers, methods, and/or theories in investigations of the same phenomenon. We applied triangulation aspects in the analysis of the effects of a computer-based nursing documentation system. *Results*: We discuss, based on this case study, what benefits can be obtained from applying triangulation in an evaluation study. We show how both the validation of results and the completeness of results can be supported by triangulation. *Discussion*: The decision whether triangulation may be useful for a given research question, and how it may be correctly applied, requires — like other evaluation methods — intensive training and methodological experience. Medical informatics evaluation research may profit from this well-established theory.
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1. Introduction

It is hard to imagine health care without modern information and communication technology (ICT). It is evident that the use of modern ICT offers tremendous opportunities to reduce clinical errors, to support health care professionals in their daily work, and to increase the efficiency of patient care. However, there are also hazards associated with ICT in health care: modern information systems are costly, their failures may cause negative effects on patients and staff, and possibly, when inappropriately designed, they may result in spending more time with the computer than with the patient. This all could have a negative impact on the efficiency of patient care. Therefore, rigorous evaluations of ICT applications in health care during their full life cycle (from design to introduction and routine use) are absolutely neces-

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sary and of great importance for decision makers and users.

Evaluation of health ICT applications is rather difficult for various reasons: the complexity of the evaluation object, comprising technical and human aspects, the complexity of the changing clinical environment, and the insufficient awareness of the need to perform evaluation studies [1]. Various evaluation studies have been published in medical informatics in the last years (e.g. examples from 2002: [2−6]), but there is still an ongoing discussion on perceived problems within evaluation projects, e.g. with regard to adequate choice of study design and study methods (e.g. [7−12]).

Evaluation research in general has long been established as an independent empirical science, dealing with the evaluation of measures and interventions. As empirical research, evaluation is based on concrete experiences in a given domain. Within evaluation research, two main (and often rather distinct) traditions can be found: the objectivist and the subjectivistic tradition [1].

The **objectivistic tradition** (also called positivistic or quantitative) is based on the assumption that an 'objective truth' exists which can be measured, explained and predicted. Researchers can come to an agreement regarding which variables should be measured. Hypotheses can be established which can be rejected based on the result of a measurement. The results of a measurement are clearly interpretable. Any subjective interpretation is not helpful, and therefore, has to be avoided. Quantitative data is better than qualitative data because it is more exact and allows comparisons and aggregation. If adequate study designs are chosen, then the results can be generalized. Generalization beyond the specific study environment is one main aim of evaluation studies. Statistical significance plays an important role in this respect. The objectivistic approach is a rather linear one, with a clear order of theory, hypotheses, sampling, analysis and interpretation.

In contrast, the **subjectivistic tradition** (also called interpretative or qualitative) stresses the context-dependency of all observations and the mutual influence of researcher and field. There is no real absolute truth, but just interpretations or versions of it. A phenomenon can thus only be analyzed from the various viewpoints of the people involved. The study design is usually rather open, leaving place for modifications during the study. Results do not give clear answers, but have to be interpreted based on their context. Different researchers can thus come to different interpretations. Conflicting interpretations are valuable to get new insights. Verbal descriptions and case studies are useful, because they help to find relationships and to built theories. Results cannot be generalized only based on some statistical argumentation, but have to be substantiated step-wise, taking into account the individuality of each object. The approach is a more cyclic one, with a steady revision and reformulation of theories, based on any new data.

Moehr has summarized the difference between both traditions by saying that the objectivistic tradition deals with achieving objectivity, while the subjectivistic approach deals with exploiting subjectivity [13].

The objectivistic approach is rather dominant in the natural sciences. The strength of this approach seems to be the exact, quantitative measurement of effects, and the potential to demonstrate causal relationships between variables. For those study types, the randomized controlled trial is normally regarded as the gold standard [11]. Its critics complain that such studies are always restricted to pre-defined variables, thus simplifying the broad and complex relationships which we can find in reality. The insistence on statistical significance of isolated relationships would limit the understanding of the multi-causality of the field, would tend to overlook important relationships not included in the study design, and would not address the significance and meaning of results for the people involved.

The subjectivist approach has its bases more in the social sciences, but is now also more and more considered in medical informatics as an important approach, especially by researchers working on social and organizational aspects of information systems (e.g. [8,14,15]). The strength of the subjectivist approach is seen in the explanation of observations and in the inclusion of the context. The researcher is open and does not follow pre-defined hypothesis. The point of view is broader, thus unexpected or new facts can be identified. Multi-dimensional complex relationships can better be analyzed. Its critics state that the interpretations are too much dependent on the researcher (low objectivity), and that results are mostly only valid for the individual case.

It is not surprising that in the medical informatics community, which deals both with the technical and the social aspects of information technology, both traditions have their proponents and opponents. However, the discussion on the scientific rigor of each tradition doesn't seem very useful as both approaches are based on rather different scientific premises. Much more important according to Bortz [16] seems to be the question: which

approach and method is most adequate in a given research situation?

When coming to evaluation methods, the researcher can choose between quantitative and qualitative methods. Quantitative methods such as standardized questionnaires and time measurements are the main methods in the objectivistic tradition, while in the subjectivist tradition, qualitative methods such as open-ended interviews and observations dominate. Quantitative approaches seem useful when a theory is already established, and when individual relationships should be quantified and validated. They are thus often used in explanative empirical research. Applications comprise measures of efficiency, costs, or acceptance. Qualitative approaches seem to be better suited when no dedicated theory is available, and when new relationships should be discovered. They are thus more used in explorative empirical research. Applications are e.g. assessment of organization structures, user resistance, role definitions, or communication patterns.

Often, a mixture of methods is applied. For example, qualitative methods are used to prepare quantitative studies, or quantitative measurements are used to support qualitative argumentation. However, there is still usually one tradition which dominates typical evaluation studies, leading to a focus either on quantitative or qualitative methods.

Many researchers point to the fact that this domination of one method or tradition may not be useful, but that a real integration of various methods from both traditions can be much more helpful to get comprehensive answers to given research questions [17]. With regard to medical informatics, is seems possible that a more balanced approach of the combination of quantitative and qualitative methods may be more helpful to assess information technology with both their social and technical aspects. The integration of the complementary methods (and even beyond this, of data sources, theories and investigators), is discussed under the term ''triangulation''.

2. Aim of this paper

The aim of this paper is to present some background on the theory of triangulation, and to discuss, based on a case study from the evaluation of a nursing documentation system, what benefits can be obtained from applying triangulation in an evaluation study.

3. The theory of triangulation

The term triangulation is used in navigation to signify a technique for the precise determination of a ship's or aircraft's position by using several reference points. Triangulation in evaluation in general means the multiple employment of sources of data, observers, methods, or theories, in investigations of the same phenomenon [18]. This approach has two main objectives: First, to support a finding with the help of the others (validation). Second, to complement the data with new results, thus to find new information, to get additional pieces to the overall 'puzzle' (completeness) [18–20].

Triangulation is, based on work by Denzin [21], usually divided into the following four types which can be applied at the same time:

- Data triangulation: various data sources are used with regard to time, space, or persons. For example, nurses from different sites are interviewed, or questionnaires are applied at different times.
- Investigator triangulation: various observers or interviewers with their own specific professional methodological background take part in the study, gathering and analyzing the data together. For example, a computer scientist and a social scientist analyze and interpret results from focus group interviews together.
- Theory triangulation: data is analyzed based on various perspectives, hypotheses or theories. For example, organizational changes are analyzed using two different change theories.
- Methods triangulation: various methods for data collection and analysis are applied. Here, two types are distinguished: within-method triangulation (combining approaches from the same research tradition), and between-method triangulation (combining approaches from both quantitative and qualitative research traditions, also called across-method triangulation). For example, two different quantitative questionnaires may be applied to access user attitudes, or group interviews as well as questionnaires may be applied in parallel.

It should be noticed that the term triangulation is only used when one phenomenon is investigated with regard to one research question.

The term ''triangulation'' is often seen strongly related to the term ''multi-method evaluation'' because methods triangulation is seen as the most often used triangulation approach. However, as we want to stress, triangulation is not limited to the

combination of methods, but also describes the combination of data sources, investigators, or theories.

Triangulation as an evaluation method is strongly discussed in many research areas such as nursing (e.g. [20,22,23]) or health services research (e.g. [24−26]). In medical informatics, however, triangulation has barely been discussed. Only few researchers explicitly mention to have applied triangulation. For example, Fitzmaurice [27] mentions to have applied triangulative methods to evaluate a knowledge-based system, however, this triangulation is not further discussed in the paper. One of the rare researchers who strongly argues in favor of multi-method evaluation is Kaplan [28]. She already applied triangulation with an extensive discussion in 1988 [29]. While many researchers argue for a multi-method approach in evaluation (e.g. [30]), the term triangulation is normally not used, and triangulation theory seems mostly to be unknown.

4. Case study: multi-method evaluation of a nursing documentation system

4.1. Background of the study

Nursing documentation is an important part of clinical documentation. Thorough nursing documentation is seen as a precondition for good patient care and for efficient communication and co-operation within the healthcare professional team. Paper-based documentation systems have been introduced to support nursing process documentation. Frequently, however, large investments in documentation efforts, low quality and limited general acceptance of the nursing process have been reported [31]. Therefore, there have been some attempts and discussions on how to support the nursing process using computer-based documentation systems [32].

In 1997, the Heidelberg University Medical Center decided to systematically evaluate preconditions and consequences of computer-based nursing process documentation, with special emphasis on acceptance and attitudes issues. We chose four different (psychiatric and somatic) departments, introduced a nursing documentation system, and conducted an evaluation study. One part of this evaluation project concentrated on questions of user attitudes, trying to analyze which changes in nurses' attitudes occurred after the introduction of the computer-based system with regard to the nursing process, computers in general, computers in nursing and the documentation system itself.

In the following paragraphs, we will concentrate on those parts of the study which are relevant for the triangulation aspects of the study. Please refer to other publications for more details on methods and results (e.g. [33−36]).

Three of the four study wards had been selected by the nursing management for the study. On all three wards, the majority of nurses agreed to participate. Ward B volunteered by themselves. Various computer-based clinical application systems have been in use for years on all four wards, such as systems for patient administration, material ordering, or staff scheduling. The four study wards belonged to different departments.

- Ward A: Psychiatry; 21 beds; 20.7 days mean duration of stay; 19 nursing staff members.
- Ward B: Psychiatry; 28 beds; 13.7 days mean duration of stay; 17 nursing staff members.
- Ward C: Pediatrics (children under 2 years); 15 beds; 4.5 days mean duration of stay; 13 nursing staff members.
- Ward D: Dermatology; 20 beds; 9.6 days mean duration of stay; 12 nursing staff members.

Our study wards were quite different with regard to nursing documentation. On wards A and B, a complete nursing documentation based on the principles of the nursing process (for details on nursing process, see [37]) had been established for several years. In contrast, on ward C and D, only a reduced care plan was usually documented. Documentation was mostly conducted in the ward office. Only on ward C were major parts of documentation were also conducted in the patients' room.

At the beginning of the study, most of the nurses were between 20 and 39 years of age. The youngest staff could be found on ward D. Some of the nurses had prior computer experience, but none had worked with computer-supported nursing documentation systems beforehand. The mean self-confidence with computers, on a scale from 1 (= insecure) to 4 (= secure), was lowest on ward C (2.2), medium on ward A (2.45) and B (2.33), and highest on ward D (3.00). All wards were sufficiently equipped with computers: two in the ward office, and one in an additional staff room. On every ward, motivated nurses were specially trained as key-users. In addition, all other health care professional team members (such as physicians) received an introduction to the computer-based documentation system on how to access the records.

4.2. Study design

The software PIK ("Pflegeinformations- und Kommunikationssystem", a German acronym for "nursing information and communication system") was chosen for the study and introduced on the four wards of the University Hospitals of Heidelberg, Germany. The functionality covered the six phases of the nursing care process. The study consisted of two main parts.

The objective of the more **quantitative study** was to analyze the changes in the nurses' attitudes with regard to nursing process, computers in nursing, and nursing documentation system, following the introduction of the computer-based system. Standardized, validated questionnaires were applied based on Bowman [38] for nurses' attitudes on the nursing process, on Nickell [39] for computer attitudes, on Lowry [40] for nurses' attitudes on computers in nursing, and on Chin [41] and Ohmann [42] for nurses' satisfaction with the computer-based nursing documentation system itself. We carefully translated those questionnaires into German and checked the comprehensiveness in a pre-study.

We used a prospective intervention study with three time measurements:

- approximately 3 months before introduction ("before");
- approximately 3 months after introduction ("during");
- approximately 9 months after introduction ("after").

The intervention was defined as the introduction of the selected nursing process documentation system (PIK) on the entire ward for all phases of the nursing care process. The study period was between August 1998 and October 2001. The measurements at the wards followed individual time schedules (see Table 1).

The second part of the study was a more **qualitative study**. Here, the objective was to further analyze the reasons for the different attitudes on the wards. The quantitative study exactly described these attitudes, and the qualitative study was now intended to further explain those quantitative results. The qualitative study was conducted in February 2002, following the completion of the analysis of the quantitative study. The decision for the qualitative study was only made when the results of the quantitative analysis were available, showing some significant differences in attitudes between the wards.

In this qualitative study, open-ended focus group interviews were conducted with up to four staff members from each ward (most of them have already have taken part in the quantitative study), with the three project managers from each department, and with the four ward managers from the wards. Open-ended means that the interviews were not guided by pre-defined questions. We used two general questions which started the interviews: "How are you doing with PIK?", "How was the introduction period" for the staff members, and "How is your ward doing with PIK?", "How was the introduction period?" for project management and ward management, respectively. We found those starting questions useful to get the participants to talk about subjective perceptions of the work with PIK. The rest of the interview was mostly guided by the participants themselves, with relatively little control exerted by the interviewers.

All interviews were conducted by a team of two researchers. They took about 1 h each. The interviews were audiotaped and analyzed using inductive, iterative content analysis (based on [17]). This means that the transcripts were carefully and

Table 1 Time of application for each of the three questionnaires and time of introduction of the computer-based nursing documentation system PIK on the four study wards

	First questionnaire ('before')	Introduction of PIK	Second questionnaire ('during')	Third questionnaire ('after')
Ward A	September 1998	November 1998	February 1999	August 2000[a]
Ward B[b]	September 1998	November 1999	—	August 2000
Ward C	May 2000	October 2000	January 2001	July 2001
Ward D	June 2000	September 2000	December 2000	June 2001

[a] The evaluation on this ward was initially terminated after the second questionnaire. After expanding the study on three other wards, ward A again joined in for the third questionnaire, about 1 and half years after the second one.
[b] Ward B was initially defined as control ward to ward A. In 2000, the ward decided to introduce PIK, and therefore, joined the study. Therefore, no second questionnaire is available.

step-wise analyzed (using the software WINMAX-PROF98), finding corresponding phrases, deriving categories, and indexing the paragraphs by those categories. This also means that no pre-defined structure was used, but instead a bottom-up approach to analyze the text.

In the following paragraphs, only those results of the quantitative and qualitative study will be presented which are relevant for the triangulation aspects of the study. Please refer to the already mentioned study publications for more details.

4.3. Results of quantitative analysis of user attitudes

All in all 119 questionnaires were returned: 23 nurses answered all three questionnaires, 17 nurses answered two, and 16 nurses answered one questionnaire. The return rates were 82% for the first questionnaire, 86.5% for the second questionnaire, and 90.2% for the third questionnaire.

Table 2 shows the results of the attitude measurements. A quantitative analysis of the individual items of the questionnaires revealed negative effects especially on ward C. Both on wards C and D, the nurses stated that the documentation system does not "save time", and that it does not "lead to a better overview on the course of patient care". In addition, on ward C, the nurses stated that they "felt burdened in their work" by the computer-based system, and that the documentation system does not "make documentation easier". On ward A and B, the opinions with regard to those items were more positive.

The self reported daily usage of the computer-based documentation system was quite similar on all wards: about 1−2 h/day during the second and third questionnaire, with highest values on ward B, and lowest values on ward A. The self-confidence with the system as stated by the nurses was rather high on all wards during both the second and third

questionnaire: the mean values were between 3.00 and 3.67 during the second questionnaire, and between 3.43 and 3.78 during the third questionnaire (1 = minimum, 4 = maximum).

Statistical analysis revealed that the overall attitude on the documentation system during the third questionnaire was positively correlated to the initial attitude toward the nursing process, to the initial attitude toward computers in general and to the initial attitude toward computers in nursing. Both computer attitude scores were in turn positively correlated to the years of computer experience (details see [33]).

Overall, the results of quantitative analysis pointed to a positive attitude toward the computer-based nursing documentation already shortly after its introduction, which significant increase on three of the four wards later on. However, on ward C, the quantitative results revealed negative reactions, showing a heavy decline in the attitude scores during the second questionnaire. On ward C, the overall attitude of the computer-based system remained rather negative, even during the third questionnaire. What could the reason be? A subsequent qualitative study was conducted in order to answer this question.

4.4. Results of qualitative analysis of user attitudes

Overall, about 100 pages of interview transcript were analyzed. First, the individual interviews were analyzed to find intra-organizational patterns. Then, the results of each interview were compared. After the results of the quantitative study, we were especially interested to better understand the reasons for the different attitudes on all wards, and especially to learn more about the differences between ward C and the other wards. Details of the interviews are published in [43], we will now only summarize the main points.

Table 2 Mean of three attitude scores (1 = most negative attitude, 4 = most positive attitude) of the four study wards for each of the three measurement points (T1 = before introduction, T2 = during introduction, T3 = after introduction of a computer-based nursing documentation system)

	Attitude on the nursing process			Attitude on computers in nursing			Attitude on the computer-based nursing documentation system		
	T1	T2	T3	T1	T2	T3	T1	T2	T3
Ward A	2.92	2.96	3.18	2.70	2.83	3.00	–	2.80	3.40
Ward B	3.36	–	3.21	3.03	–	3.30	–	–	3.64
Ward C	2.78	2.00	2.53	2.43	2.04	2.65	–	2.17	2.33
Ward D	2.94	3.03	3.15	2.91	3.04	3.17	–	3.25	3.75

Only answers from the 40 nurses that answered all available questionnaires are included.

On ward C, some distinct features came up in the interviews which seem to have lead to low attitude scores at the beginning. For example, the nursing process had not been completely implemented before. Documentation of nursing tasks covered a 24 h/day, due to the very young patients and their great need for care. Thus, the overall amount of documentation on ward C was higher. Patient fluctuation was also highest on ward C. For each patient, a complete nursing anamnesis and nursing care plan must be established, which is in the opinions of the nurses more time-consuming than it had been before. The previous computer experience was seen as rather low on ward C, and also the number and availability of motivated key users. Then, during the introduction of the nursing documentation system, the workload was rather high on ward C due to staff shortage which increased pressure on the nurses. Finally, and most importantly, nursing documentation had previously at least partly been carried out in the patients' rooms. However, during our study, computers were only installed in the ward office. No mobile computers were available, which according to the nurses lead to double documentation. Thus, the ward was forced to change their documentation patterns which then also affected the communication patterns within the health care professional team. Even at the time of the interviews, those changes did not seem to have been completely integrated into the daily routine.

Interesting differences were found between the nurses and the project management on ward C. For example, the nurses stated in the interviews to not have been sufficiently informed on the new documentation system, while the project management stated to have offered information, which had, however, not been used. Another example: the nurses felt that training was insufficient. In the opinion of the project management, sufficient opportunities had been offered. We will later see how this divergent information helps to complete the overall picture.

On ward D, the attitude toward the documentation system was high in the interviews. The nurses saw benefits, especially in a more professional documentation, which would lead to a greater acknowledgement of nursing. Standardized care planing was seen to make care planning much easier, without reducing the individuality of the patient. Greater time effort through a more complete documentation was not discussed. The role of the computer-based system in communication seemed to be rather clear: it supported, but did not replace, oral communication. Overall, ward D felt at ease while working with the new documentation system.

On ward A and B, the attitudes were also positive. The nurses stressed the better legibility of nursing documentation in the interviews. They said that time effort for nursing care planning was lower, but overall, time effort for nursing documentation was much higher than before. The nurses wanted to use the documentation system to support oral communication with the physicians on the ward, but this did not really work. The interviews showed that the introduction period had been filled with anxiety and fear about new requirements for the nurses. Now, after some time, the nurses felt self-confident with computers. Some interviewees focused on the problems of data security, pointing to the fact e.g. that the psychiatric diagnosis may now be much better available to unauthorized persons than before. An interesting discussion also arose on the topic of standardization. Most nurses felt that standardized care plans reduce the individuality of the care plans, and that they do not really reflect what is going on with the patient. Finally, those wards, too, mentioned insufficient teaching and support in the first weeks.

These rather short summaries from the interviews should highlight some distinct features of the wards, showing similarities (e.g. on insufficient teaching and fears at the beginning), but also differences (e.g. on the question regarding standardized care plans or time effort).

4.5. Application of triangulation in this study

Following the analysis of the quantitative study and the qualitative study, we now want to see how the different results can be put together to get a broader picture of the effects and preconditions of a nursing documentation system. We thus applied all four types of triangulation as described by Denzin [21]:

- Data triangulation: various data sources were used: within the quantitative study, data triangulation with regard to time was used as the questionnaires were submitted three times to the same users (data triangulation with regard to time). In addition, in the interviews, not only nurses, but also project management and ward management were interviewed (data triangulation with regard to persons).
- Investigator triangulation: within the qualitative study, the two interviewers had different backgrounds (one more quantitative coming from

medical informatics, the other more qualitative coming from social science). Both acted together as interviewers, analyzed the transcript together, and discussed and agreed on results and conclusions.

- Theory triangulation: we learned from various complementing theories to better understand the results of our studies. For example, to explain the implementation phases, we took ideas both from Lorenzi (first-, middle- and second-order change, [44]) as well as from the change theory of Lewin (unfreezing, moving, refreezing phase, [45]). With regard to user evaluation, we used e.g. the Technology Acceptance Model (TAM) of Davis [46], and the Task-Technology Fit model (TTF) of Goddhue [47].
- Methods triangulation: we applied between-methods triangulation by applying both quantitative questionnaires and qualitative focus group interviews to investigate users attitudes.

As stated in the introduction, triangulation has two main objectives: to confirm results with data from other sources (validation of results), and to find new data to get a more complete picture (completeness of results). We will now shortly discuss whether triangulation helped to achieve those goals.

4.6. Validation of results

Validation of results is obtained when results from one part of the study are confirmed by congruent (not necessarily equal) results from other parts of the study. In our example, some parts of the study showed congruent results.

First, both the questionnaire and the interviews focused on attitudes issues. In this area, both approaches lead to congruent results, showing e.g. favorable attitudes on three wards. In addition, both the questionnaires and the interviews showed problems with regard to the user satisfaction with the nursing documentation system on ward C. However, as the interviews were conducted later, they could better show the long-term development on the wards. Hence, both data sources thus showed congruent results.

Another example are the congruent results of the two scales "attitudes toward nursing process" and "attitude toward the computer-based nursing documentation system" within the standardized questionnaires. Both focus on different attitude items and both showed comparable low results on ward C and higher results on the other wards, pointing to congruent measurements.

Those two selected examples show how results of some parts of the study could be validated by congruent results from other parts of the studies.

4.7. Completeness of results

Besides validation, triangulation can increase completeness when one part of the study presents results which have not been found in other parts of the study. With this new information, the completeness of results is increased. The new information may be complementary to other results, or it may present divergent information.

In our study, both questionnaires and interviews presented partly **complementary results**, which led to new insights. For example, impact of the computer-based documentation system on documentation processes and communication processes had not been detected by the questionnaire (this aspect had not been included in the questions). However, the documentation system seems to have influenced e.g. the way different health care professional exchanged patient-related information. This led to some discussion on this topic on all wards in the interviews and seems to have had an impact on the overall attitude. Those effects only emerged in the group interviews (and not in the questionnaires), enlarging the picture of the effects of the nursing documentation system, and helping to better understand the reactions of the different wards.

Another example is the complementarity of the results in the interviews and questionnaires on ward C. The interviews were done some time after the questionnaires. Thus, during this time, changes may have occurred. The change theory of Lewin [45] states that organizational changes occur in three phases. "Unfreezing" (old patterns must be released, combined with insecurity and problems), "Moving" (new patterns are tested), and "Refreezing" (new patterns are internalized and seen as normal). The low attitude scores on ward C even at the last measurement point (see Table 2) indicate that the ward was in the moving phase during this time. During the interviews, the stress which was articulated by the nurses seemed to be less — even while problems were mentioned, the ward seems to have adapted to the new situation. This can be interpreted of ward C being slowly changing from the moving into the refreezing phase.

Triangulation can thus help to get a more complete picture of the object under investigation. Often, especially when applying various methods during the investigation, the results will not be congruent, but they may be divergent (e.g. contradicting). This is an important aspect of triangula-

tion, as divergent results can especially highlight some points, present new information and lead to further investigation.

In our study, we found some **divergent results** in our study. For example, during the group interviews, nurses from one ward stressed that they do not see a reduction in effort needed for documentation by the computer-based system. However, in the questionnaires, this ward indicated strong time reductions. These differences can lead to the questions whether e.g. time efforts are judged with regard to the situation without the nursing documentation system (where amount of documentation was much lower, and so did the time effort), or with regard to the tasks which have to be performed (the same amount of documentation can be done much quicker with the computer-based system). This discussion can help to better understand the answers. Interesting differences of point of view could also be found between the staff and the project management of one ward in the group interviews. While the nurses of this ward claimed in the interviews that training was suboptimal, the project management stated that sufficient offers had been made. Those apparent contradictions may point e.g. to different perceptions of the need for training by the different stakeholders. Those insights may help to better organize the teaching on other wards.

As those (selected) examples show, triangulation helped us to obtain a better picture of the reactions of the four wards. The results of both the quantitative and the qualitative study were intensively discussed with the nursing management, with the project management, and with the ward management, to learn how to better design the introduction phase of nursing documentation systems in the future. The results also led to some decisions on how to improve the technical infrastructure as well as how to better organize the teaching and support on some wards. All wards are still working with the computer-based nursing documentation system.

We will now focus on the discussion of triangulation as an evaluation method.

5. Discussion

Greene stated that a mixed-method evaluation design can be differentiated along two dimensions [18]: (a) the degree of independence of the quantitative and qualitative data collection and analysis activities, and (b) the degree to which the implementation of both methods is sequential or concurrent. In this terminology, our study mostly applied independent methods triangulation (we applied different study plans, different investigations, partly different observers, and we published different reports for both the quantitative and the qualitative study), and a more sequential one (where the motivation and approach of the qualitative study built on quantitative results). The impact of such a sequential approach is that the various data collections are done at different times, which can lead to differences in the results—but which can also provide new information by triangulation (e.g. with regard to the change phase a ward is just in).

While triangulation has long been discussed and applied in research (one of the first being Campbell and Fiske, [48]), the idea of the possible advantages of multi-method approaches or triangulation in more general terms has not yet been broadly applied in medical informatics research. As far as we know, one of the rare explicit examples can be found in a paper by Kaplan [29], where she applied the combination of quantitative and qualitative methods in the evaluation of a laboratory information system. Many researchers may apply parts of triangulation methods (e.g. by adding free-text fields to quantitative questionnaires), without being aware of the theoretical foundations and the benefits of an explicit triangulation. A broader knowledge of the theory and usefulness of triangulation is not reflected in the medical informatics literature.

As nearly every introduction of information and communication technology is also combined with complex organizational changes, qualitative methods seem to be especially suited to analyze the individual and specific consequences and problems. Qualitative approaches better help to understand how the staff came to the subjective assessment of cost and benefits of the new technology, i.e. which facets were included in the assessment, and how they were weighted by the individual users. Quantitative approaches, on the other side, can quantify the results of this individual assessment. For example, in our case, the quantitative results showed unfavorable attitudes on ward C. However, only the qualitative interviews brought some more details on the reasons. But, certainly, qualitative methods can also have some disadvantages. For example, they do not normally allow to analyze larger numbers of objects (as quantitative methods do), their application is rather time-consuming, and a high methodological standard is needed to guarantee internal and external validity.

In general, both quantitative and qualitative methods have their areas and research questions

where they can be successfully applied. By triangulation of both approaches, their advantages can be combined. For example, both methods can smoothly be built on one another, e.g. by using the results of the qualitative analysis to design a more quantitative study focusing on changes in communication patterns, or by using qualitative interviews to help to better explain quantitative findings. The mutual possible contributions of quantitative and qualitative methods are further discussed e.g. in [24]. It should, however, not be forgotten in this discussion that triangulation cannot only be applied to methods, but also to data sources, investigators, and theories, offering the evaluation researcher a broader basis to better understand evaluation results.

The two major objectives of triangulation, as described before, are validation of results and completeness of results. However, it can also be argued that data of different types (e.g. words, figures) or data obtained by different sources (e.g. standardized, not standardized) cannot really validate each other, as they present different perspectives, and can, therefore, not really be congruent (e.g. a quantitative increase in acceptance scores is not really the same as the statement "we got used to it" in an interview). However, they can certainly complement each other, and they can even be divergent. We found that both complementary and divergent results from the different sources gave important new information and stimulation of further discussion. While complementary results contain at least some sort of validation (while also broadening the picture), divergent results can lead to further investigation to explain the found discrepancies (which also broadens the picture).

The limitations of triangulation must also be discussed. For example, Belgey [20] states that some researchers seem to expect that "the mere fact they are utilizing triangulation will magically solve all problems of bias, error and invalidity" in their research. But that is certainly not the case, and triangulation as a method must be as thoroughly applied as other evaluation methods. Each individual approach has its potentials, and many research questions can be adequately answered without complex triangulation approaches [23,24]. Thus, the research question is the most important criterion, and the researcher has to deliberately decide and give reasons for whether or not he wants to apply triangulation [20]. When multi-method triangulation is applied, the strengths and weaknesses of the chosen method should complement each other [49]. It also has be considered that the more methods that are applied, the more time

the study may take. Especially qualitative methods and the triangulation of results require an aggregating and time-consuming approach before clear results can be presented. Sometimes, quantitative methods may be regarded as easier to apply when budget or time restrictions exist.

In the last years, there has been a more basic discussion whether inter-methods triangulation is possible at all. It is discussed that the epistemological underpinnings between quantitative and qualitative research paradigms may be so different that a real combination may not be possible (e.g. [18,23,24]). However, this argumentation does not take into account that a tradition of research has formed beyond subjectivistic and objectivistic paradigms. Evaluation methods are chosen accordingly to the research questions and the research topic. Thus, the question which methods to apply and how to combine them can only be answered with respect to the research topic and the research question, and not on a general basis.

Thus, as important as this discussion might be in the light of progress in research methods, evaluation researchers in medical informatics may be advised to start to select and combine methods based on their distinctive research question. Even when research is strongly based in the quantitative tradition, qualitative elements can help e.g. to identify quantifiable variables, to explain quantitative findings or to derive further research questions. And, in qualitative research, quantitative approaches can help e.g. to quantify qualitative categories, or support sampling.

In addition, evaluation researchers should take into account that triangulation is not limited to methods triangulation (even as it is the most broadly used type of triangulation), but also simpler types of triangulation such as triangulation of various data sources, of investigators with various backgrounds (a nice example can be found in [29]), or of theories. This gives evaluation researchers a broad range of possibilities to increase both completeness and validity of results independent of his or her research tradition.

6. Conclusion

We have presented some basics on triangulation and illustrated them in a case study. The correct application of triangulation requires —as other evaluation methods— training and methodological experience. Medical informatics evaluation research may profit from this well-established theory. Evaluators need help to decide which (quantitative or qualitative) methods may be able

to answers his or her research question, and where triangulation (of data, investigators, theories or methods) may be useful. Therefore, we should strive for a comprehensive evaluation guideline which helps to answer those questions, and which helps to design better evaluation studies. This may lead to better information systems and finally to a better support of patient care.

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