Assessing User-Designed Dashboards: A Case for Developing Data Visualization Competency

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Abstract

Health information dashboards, which are collections of relevant indicator visualizations for management, have become a common feature and strategy for improved information use in the health sector. They should provide any manager with quality information in a format that points out the performance of health service provision, and thus necessitate good knowledge of visualization techniques to both develop and interpret. Since health management is a dispersed and decentralized activity, dashboards need to be relevant to varied users, and various administrative levels of the health services. This can be achieved by enabling all users to make their own dashboards, based on the indicators they need, and presented in a suitable manner to track the local priority activities.

In this study we examine user-defined dashboards in Indonesia, which has implemented a flexible and open source platform for health management (DHIS2). While the technical flexibility of the platform has been taken advantage of by providing platform customization training, the study finds that the quality of the dashboards created face numerous challenges. These challenges point to poor visualization competence. We conclude by calling for such competence to be addressed by the training curricula, as well as by utilizing existing "best practice" dashboards from WHO now available for the same platform.

Keywords: Dashboard design, Open source platform, Data visualization literacy, Capacity building.

1   Introduction

Ever since the beginning of ICT4D research, the applied domain of health services has been an important topic. This is both due to the importance of health for development, and the wide variety of digitalization efforts seen in the sector. Despite progress and advances in the use of ICT for health development, many problems in diverse program areas remain unaddressed, thus leaving spaces for research and innovations [1,2]. Design, governance, and sustainability are a recurring set of issues faced by health information systems (HIS) in developing countries [3].

The central focus of our paper concerns the adaptation work needed on a free and open source platform for health management. A platform is by default a half-product [4], where the real value lies in the ability to accommodate tailored solutions on the

more generic and stable core part of the system. Considerable work is typically needed to customize such half-products to any given organizational context. To use such platforms, Msiska and Nielsen [5] argue for the need for diverse capacities related to platform deployment, customization, and use.

We do this by looking at the implementation of DHIS2 (District Health Information Software) in Indonesia. This software platform is rooted in a philosophy of decentralized adaptation and contextualized use [6]. With local health variations, it was at the software's inception two decades ago designed to not only accommodate, but actively encourage local adaptation.

DHIS2 customization and use requires different sets of skills and allows multiple ways of adapting and adopting the software [7,8]. The literature coming out of projects implementing DHIS2 has explored the processes and skills required both to innovate the platform by development and modification of apps and modules within DHIS2 [5], and to use the existing end-user interface features [9]. In this paper we focus on the latter, where end-users themselves customize the software to their needs.

We specifically look at local adaptation of dashboards, which are collection of various user-defined visual and tabular information. Across Indonesia, health staff at national, provincial, and local level have been trained in using DHIS2, including how to make their own dashboards for routine health service provision monitoring. The training has focused on how to customize DHIS2, while the decisions on what the dashboards should display and how this information should be displayed has been up to the various users to decide.

The creation of dashboards entails at least the bringing together of domain knowledge from ICT and health. However, as we will argue, there are other skills that are as important to fully utilize the new functionalities the introduction of ICT included. In our case, skills related to visualization and communication of information need a stronger focus in the development of locally appropriate systems.

This paper attempts to answer following empirical research question: What are the challenges of user-designed dashboards? Analyzing such dashboards in Indonesia will then inform our understanding on the skills and capacities needed to leverage these functionalities of the flexible digital platform.

We organize this paper as follows. In next section, we will examine literature on dashboard design and data visualization capacity, followed by a case study of dashboard design practice by end-users in Indonesia. We also propose a tool to evaluate dashboard and data visualization modified from Few's list of common dashboard design mistakes [10] and practical recommendations on dashboard design and data visualization capacity building.

2 Related Literature

2.1 Health Dashboard and Information Use

The underlying philosophy of the DHIS2 software is that health service provision should be managed through an integrated district health system. This idea of a health

district as an administrative geographical entity is rooted in the World Health Organization's Alma Ata declaration on primary health care, and is seen as the ideal unit for local health management [11]. The size of a district is dependent on a balance between resources, autonomy, and closeness to the health service provision.

Local use of the information is a consistent challenge in managing public health service. Despite the early identification of the need for building local capacity for evidence-based management [12], there is still not much evidence on the ground of improved information use at district level [13]. Lately, there has been an international effort to address this led by WHO to develop best-practice dashboards for various health programs, and provide them as downloadable packages for DHIS2 to provide some consistency in what and how data is displayed [14, 15]. A dashboard is a collection of key performance indicators for any given area, displayed in various visualizations where the aim is to improve routine monitoring, and has for some time been applied in health information systems in developing countries [16].

2.2 Data Visualization Competency of Health Staff

Appropriate and relevant dashboards are not straightforward to make. All users of dashboards need data literacy in order to read graphs and tables appropriately and to recognize misleading or inappropriate use of such [17]. In addition to that, to create dashboards, users need to understand data visualization techniques to avoid creating misleading or ambiguous data visualizations [18]. Such proficiency is also specific to the discipline or domain in question, such as health, and not necessarily generically applicable. Few [10] lists common mistakes with dashboard design, ranging from clutter, inappropriate contextualization, to wrong use of visualization techniques.

Data visualization proficiency is thus needed at local level when the technology promotes local adaptability of dashboards. This devolution is in line with reducing the gap between developers and users of technology [3, 19], but it raises the issue of the appropriate skills being present [5, 7]. The training of local health staff to appropriately use the technology of choice for health management need to take this into account. There is an urgent need to understand the current practice and challenges of making locally relevant dashboards.

3 Research Design

Case study was chosen to achieve the research objectives as it allows researchers to study IS in its natural settings [20]. This research design is highly versatile in ICT research [21] and is appropriate for exploration of a flexible platform adoption such as DHIS2. The case investigated is the use of dashboards in the DHIS2 platform as applied in Indonesia, through carrying out quantitative and qualitative analysis of a subset of the dashboards.

3.1 Case overview

The initiative to implement DHIS2 in Indonesia originated from the need for data integration from different sources across health programs such as HIV/AIDS, Tuberculosis, Malaria, Immunization, Nutrition, Mother and Child Health (MCH), to be available at health administration levels such as health care facilities and district health offices. Once data from different programs reach the DHIS2 data warehouse, they can be visualized through maps, graphs or tables. Finally, various visualizations can be displayed together in health program dashboards (see **Fig. 1**).

Fig. 1. Sample of tuberculosis program dashboard in DHIS2

The platform was rolled out in 5 provinces in Indonesia in 2017. Training curricula and material for health program managers and health information system staff include how to create and manage visualizations and dashboards. The initial implementation included 5 provinces, 10 districts, and 100 healthcare facilities implementing DHIS2 dashboards in the country.

During the roll out, each district and province was mandated by the MoH to develop dashboards for at least 6 focus health programs (HIV/AIDS, Tuberculosis, Malaria, MCH, Immunization, and Nutrition). In addition, each facility was required to create at least one cross-program dashboard that contained data from above programs. The ministry also encouraged the districts and facilities to routinely analyze, present, discuss, and use the data in their dashboards, including in routine meetings for health program planning and decision making. By their own initiatives, many of these entities also created dashboards for their own local needs. For example, several districts created home care and environmental health dashboards although they are not mandatory. This is consequently followed by the emergence of a high number of health program dashboards.

While development of standards for visualizations, including indicators, data analysis, and dashboards was initiated in the pilot implementation in 2015, no such standardized guidelines for dashboards could be documented in the case study. Varied ways of data visualization and dashboard management had emerged, based on the unique ways these different entities interpreted the national mandate to develop the dashboards.

By default, dashboards created by users are saved as private dashboards. But users can choose to share the viewing or editing authority with particular users, user groups, or all users in the instance.

3.2   Data collection

This study included three steps which are: (1) collecting screenshots of 316 shared dashboards in use in Indonesia, representing all implementation level of the dashboards (national, province, district, and facility level), (2) conducting quantitative and qualitative analysis of 80 (25.3%) of these dashboards to see how they are applied for various health programs and administrative areas.

To standardize the time of assessment, all dashboards were screenshot on July 11, 2018. For the purpose of this research, we limited analysis to the dashboards that are shared to national level user group with an assumption that by sharing their dashboards, the creators are confident of the quality of their dashboard, both in terms of data visualization and data quality.

3.3   Data analysis

Eighty dashboards were randomly selected from the pool of 316. Quantitative analysis was conducted to assess the following dimensions; which administrative level they represented, which health programs they included, the content in terms of selected indicators, time periods, and types and number of visualizations.

From Few's [10] common dashboard design problems, we developed relevant qualitative assessment criteria that would fit the nature of the DHIS2 dashboards. For example, we would look for appropriateness of a visualization method in conveying the intended information. After analyzing the dashboards, we categorized them in 5 main problem categories as only a subset of Few's problem categories are relevant for the user-defined dashboards in question (**Table 1**).

Table 1. Dashboard problem categories (Adapted from Few [10]).

Problem category	Description
Context problem	Dashboard or data visualizations are unable to provide context or significance, or providing false or misleading meaning for the health program planning and management.
Layout problem	Problems related to how the indicators and visualizations are arranged
Visualization technique problem	Problems related to the choice of chart types or management within an individual chart; such as choice of indicators, time period, or organization units, stack style, etc.
Logical problem	To build into a comprehensive and logical context or story of a program achievement, logical order of presented, compared, and analyzed indicator and visualization is needed. Failing to visualize with logical order may not create contextual problem de-

	pending on the dashboard or visualization reader.
Data quality problem	As an addition to how the data are presented in the dashboard and how the dashboard is organized, we also found data quality issues that need to be revisited to allow informed information use. This include incompleteness, inconsistency, and inaccuracy of the data.

4 Dashboard Analysis

From the 316 dashboards, analysis was done to 80 (25.3%) dashboards with results shown in **Table 2** and **3**. The majority of the dashboards analyzed were from district and facility levels; 45% and 26.25%, respectively. This is relevant as the emphasis on technical assistance for dashboard implementation in the context was to district and facility levels. In terms of dashboard topics, majority were focused on the six targeted programs (60%) and the rest are evenly split into general dashboard (20%) and dashboards on other health programs (20%) such as environmental health, home care, other communicable diseases, etc.

Table 2. Overview of dashboards

Org Unit Level		Dashboards having these types of visualizations	
- National:	4 (5%)	- Map	29 (36.25%)
- Provinces:	10 (12.5%)	- Table	27 (33.75%)
- Districts:	36 (45%)	- Bar/Column	70 (87.5%)
- Facility:	21 (26.25%)	chart	45 (56.25%)
- Not specified	9 (11.25%)	- Other	
Programs		**Freq. of visualization counts**	**Freq. of visualization types**
Focus program	*48 (60%)*	- 0-4 32 (38.1%)	- Bar 137 (25%)
HIV/AIDS	6	- 5-9 26 (30.1%)	- Column 189 (34.5%)
TB	9	- 10-14 13 (15.5%)	- Line 63 (11.5%)
Malaria	7	- 15-19 5 (5.9%)	- Table 48 (8.8%)
MCH	9	- >19 4 (4.7%)	- Map 48 (8.8%)
Nutrition	8		- Pie 36 (6.6%)
Immunization	9		- Others 26 (4.7%)
Other program(s)	*16 (20%)*		
Not program specific	*16 (20%)*		

On the visualization methods, bar and column charts are the most popular as they appear in 87.5% of all the examined dashboards; followed by map (36.25%) and table (33.75%). Half of the dashboards (56.25%) had other visualization methods (spider, pie, area, line, speedometer charts). All the examined dashboards show 547 visualizations or an average of 6.83 visualizations per dashboard. Although map and table are relatively popular visualization methods, there are only 48 maps and 48 tables in 29 and 27 dashboards, respectively, meaning only less than 2 maps or tables are used per dashboard. It is a contrast with 326 bar and column charts that appear in only 70 dashboards, or more than 4 per dashboards in average. Majority of the dashboards have

less than 10 visualizations (72.5%); while only 5% of 80 dashboards show 20-38 visualizations.

Although Few [10] has pointed out that the whole dashboard has to be visible in one full screen, with the responsive web design and access from mobile phone, it is no longer a strict guide to follow. In addition to that, guidelines from WHO [20] recommends 2 to 9 visualizations per dashboard for TB, HIV/AIDS, and nutrition; and 26 and 30 visualizations for malaria and immunization. These suggested numbers are related to the nature of the program. However, the guidelines also show that the visualizations can be grouped and arranged to ensure that the dashboard is easy to read and easy to understand. The analysis based on Few's criteria [10] is shown in Table 3.

Table 3. Frequency of dashboard problems

Problem type	Frequency
Context problem	61 (73.5%)
Dashboard layout problem	35 (42.2%)
Visualization technique problem	69 (83.1%)
Logical problem	47 (56.6%)
Data quality problem	28 (33.7%)

4.1   Context problem

Problems of contextualization was the second most common mistake, with over three quarters of dashboards showing such challenges. This type of problem includes 1) no message that can be drawn, be it from collective data visualizations, that is either comprehensive or useful for program monitoring, planning, or decision making, 2) visualizations are not communicating with each other, 3) visualizations that are not clearly described through title, subtitle, legend or label thus context is not easily understood, or 4) individual or collective visualizations are not aligned with the purpose, theme or topic of the dashboard.

4.2   Dashboard layout problem

This challenge was found in 42.2% of the dashboards. While still a high figure, it represents the least common item in our list, showing the acute problems found in the dashboards. Dashboard layout problems are related to dashboard clutters or the use of too many visualizations in one dashboard, unnecessary gaps or empty spaces on the screen. Despite this, the problem is relatively easy to fix and is not critical to information use and decision making compared to other problems.
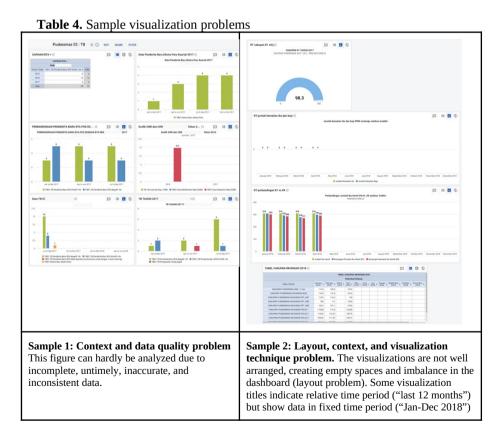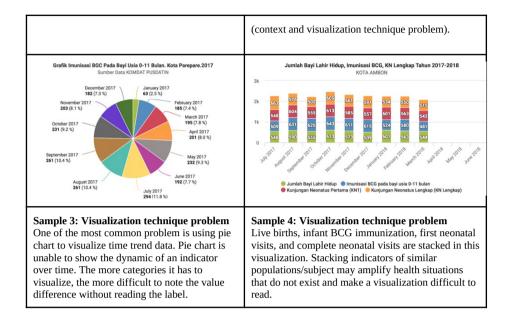
4.3   Visualization technique problem

Among all 80 examined dashboards only 11 did not experience visualization technique problem. The typical cases in this problem category includes 1) inappropriate choice of visualization type for particular dataset or analysis, for example the use of

pie or spider chart for time trend data or even repeated visualization of indicator(s) for the sake of visualization variation, 2) inappropriate modes such as stack or non-stacking, 3) inappropriate choice of time period or indicators that result in the presentation of irrelevant time period for analysis or comparison of unrelated indicators or indicators with high with low figures such as total population with case finding, 4) poor choice or management of indicator, time period, or organization unit that causes clutters, etc. In many cases, this type of problem also causes other problems such as context problems and layout problems.

4.4   Logic problem

To build comprehensive understanding and insight of program performance, either for monitoring, planning, or decision making; the logical and chronological management of visualizations within a dashboard, indicators within a visualization, and time period is important. For example, in tuberculosis program, it is more common and easier to manage the cohort cases from the active case finding, diagnosis confirmation, treatment given, to the treatment results. Same works for cross program management such as MCH and immunization that chronologically managed from pregnancy, delivery, baby services including baby immunizations.

Table 4. Sample visualization problems

| **Sample 1: Context and data quality problem** This figure can hardly be analyzed due to incomplete, untimely, inaccurate, and inconsistent data. | **Sample 2: Layout, context, and visualization technique problem.** The visualizations are not well arranged, creating empty spaces and imbalance in the dashboard (layout problem). Some visualization titles indicate relative time period ("last 12 months") but show data in fixed time period ("Jan-Dec 2018") |

	(context and visualization technique problem).
Sample 3: Visualization technique problem One of the most common problem is using pie chart to visualize time trend data. Pie chart is unable to show the dynamic of an indicator over time. The more categories it has to visualize, the more difficult to note the value difference without reading the label.	**Sample 4: Visualization technique problem** Live births, infant BCG immunization, first neonatal visits, and complete neonatal visits are stacked in this visualization. Stacking indicators of similar populations/subject may amplify health situations that do not exist and make a visualization difficult to read.

4.5 Data quality problem

Another common problem (33.7%), which is not related directly dashboard design, is low data quality such as incomplete data, inaccuracy, and inconsistency. Many dashboards show visualizations with missing data that can be caused by: 1) poor data quality in data source; 2) problem(s) in defining or customizing the indicators; or 3) problem(s) of data transfer from other data sources.

5 Capacity to Visualize Data and to Create Dashboard

During DHIS2 roll out in early 2017, a team consisting of DHIS2 consultants from national and district level provided training to the health staff. Prior to the training, data had been integrated from several sources into DHIS2. The staff were trained in how to use DHIS2 to make dashboards over 2 days: 1) getting familiarized with the platform interface, 2) creating visualizations (tables, graphs, and maps) with the integrated data, then 3) presenting them in dashboard(s).

This training was then followed by series of capacity building activities, delivered during monitoring visit conducted quarterly from 2017 to 2018. MoH and consultants from international and national level trained the health staff to import their data and manually enter their data. However, due to budget limits, in these follow up visits, the training was only delivered to district health staff and some health care facilities staff.

The majority of health staff who created the data visualizations and the dashboards came from different educational background such as public health, midwifery, medicine, information systems, and computer sciences disciplines. Data management competency, which comprises data visualization literacy, to our knowledge has not

yet been required to be included in health workforce competency standards. As an example, data management skill appears in competency standards of public health graduates [22] but not listed in competency standards of midwive graduates [23].

In addition to that, how data visualization training is delivered and how competent the graduates are, are still yet to be understood. This paper, however, provides initial knowledge on how health staff visualize data and design their dashboards which portrays data visualization literacy of health staff in the field.

6   Discussion

While the case illustrates that the users at district level in Indonesia are able to technically make dashboards in DHIS2, data visualization skills are low, echoing existing literature [17, 18]. The various users had been given training in how to use DHIS2, but visualization competency was not part of the curriculum. Such skills are also not part of the required competencies for the relevant positions. After adopting the framework for dashboard design by Few [10], the most common challenges found are visualization technique and context problems. A large majority (83.1%) of assessed dashboards were marked as having visualization technique problems, typically relating to the choice of chart type and management of indicators within the chart. 73.5% of dashboards were found to have issues with contexts. Logical problems and layout problems were not so frequent, relatively speaking. In addition, poor data quality was also a common finding, although was not necessarily linked to the design of the dashboards themselves.

A clear implication of poor dashboard design is false interpretations of presented data and information that are potential to lead to poor decision making, planning, and resources allocation in health program management.

7   Concluding Remarks

The dashboards were made by district staff across Indonesia, which bears testimony to the flexibility and relative ease of use of the dashboard design functionality. This is in line with both the stated aim of the Ministry of Health, as well as the underlying philosophy of local customization that is inscribed in DHIS2. However, it is not enough to place the user-as-designer to make appropriate technology if the right skills are not present. The flexibility of the technology necessitates skills that go beyond mastering the technology itself (DHIS2) and having good knowledge in the domain of application (health). Data visualization techniques is also a set of crucial skills needed to make the fullest of the introduction of the technology. One outcome of this study has been to document the key challenges related to dashboard design and visualization proficiency among district users in Indonesia. Further capacity building in the use of DHIS2-based system should be adjusted to include also these aspects.

In addition to including data visualization techniques in the training curriculum, a complementary approach would be to make use of the WHO standard disease dashboards which are now available to download to DHIS2. In the case of these not being

fully relevant for the local context, they can still be adjusted and can be used as templates for local adaptation that would help district and facility staffs to make meaningful dashboards themselves.

Apart from the data visualization literacy for health information use, data quality remains to be an issue. The root problem of incomplete, inaccurate, and inconsistent data needs to be investigated and addressed.

References

1. Walsham, G. (2017). ICT4D research: reflections on history and future agenda. *Information Technology for Development*, *23*(1), 18–41. https://doi.org/10.1080/02681102.2016.12464 06
2. Mukherjee, A. S. (2017). Empowerment: The invisible element in ICT4D projects? The case of public health information systems in India and Kenya. University of Oslo, Norway.
3. Heeks, R. (2010). Do information and communication technologies (ICTs) contribute to development? *Journal of International Development*, 22(5), 625–640. https://doi.org/10.1002/jid.1716/abstract
4. Dittrich, Y. (2014). Software engineering beyond the project–Sustaining software ecosystems. Information and Software Technology, 56(11), 1436-1456.
5. Msiska, B., & Nielsen, P. (2017). A Framework to Assess and Address Human Capacities Needed to Leverage Open Source Software Platforms in Developing Countries. In *ICT4D 2017, IFIP AICT* (Vol. 504, pp. 81–92). https://doi.org/10.1007/978-3-319-59111-7.
6. Braa, J., & Hedberg, C. (2002). The Struggle for District-Based Health Information Systems in South Africa. *The Information Society*, *18*, 113–127. https://doi.org/10.1080/01972240290075048
7. Roland, L. K., Sanner, T. A., Sæbø, J. I., & Monteiro, E. (2017). P for Platform. Architectures of large-scale participatory design. *Scandinavian Journal of Information Systems*, *29*(2), 2–34.
8. Hanseth, O., & Bygstad, B. (2015). Flexible generification: ICT standardization strategies and service innovation in health care. *European Journal of Information Systems*, *24*(6), 645–663. https://doi.org/10.1057/ejis.2015.1
9. Saugene, Z. (2013). Customization of Generic Open Source Software for Health Sector in Developing Countries. University of Oslo, Norway.
10. Few, S. (2006) *Information Dashboard Design*. CA: O'Reilly.
11. Gorgen, H., Kirsch-Woik, T., & Schmidt-Ehry, B. (2004). *The District Health System Experiences and Prospects in Africa: manual for public health practitioners*. Deutsche Gesellschaft fur.
12. Pappaioanou, M., Malison, M., Wilkins, K., Otto, B., Goodman, R. A., Churchill, R. E., ... & Thacker, S. B. (2003). Strengthening capacity in developing countries for evidence-based public health:: the data for decision-making project. *Social science & medicine*, *57*(10), 1925-1937.
13. Wickremasinghe, D., Hashmi, I. E., Schellenberg, J., & Avan, B. I. (2016). District decision-making for health in low-income settings: a systematic literature review. *Health Policy and Planning*, 31(suppl_2), ii12-ii24.
14. WHO. (2018). *Analysis and use of health facility data: General principles*.
15. Poppe, O., Sæbø, J. I., Nielsen, P., & Sanner, T. A. (2017). Standardising Through Software. *Selected Papers of the IRIS*, 8(2017), 4.

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16. Mutale, W., Chintu, N., Amoroso, C., Awoonor-Williams, K., Phillips, J., Baynes, C., ... & Sherr, K. (2013). Improving health information systems for decision making across five sub-Saharan African countries: implementation strategies from the African Health Initiative. *BMC Health Services Research*, 13(2), S9.
17. Schield, M. (2004). Information literacy, statistical literacy and data literacy. *IASSIST QUARTERLY* (IQ).
18. Carlson, J., Fosmire, M., Miller, C. C., & Nelson, M. S. (2011). Determining data information literacy needs: A study of students and research faculty. *portal: Libraries and the Academy, 11*(2), 629-657.
19. Suchman, L. (2002). Located accountabilities in technology production. *Scandinavian journal of information systems*, 14(2), 7.
20. Benbasat, I., Goldstein, D. K., & Mead, M. (1987). The Case Research Strategy in Studies of Information Systems Case Research. *MIS Quarterly, 11*(3), 369–386. https://doi.org/10.2307/248684
21. Cavaye, A. L. M. (1996). Case study research: a multi-faceted research approach for IS. *Info Systems J*. https://doi.org/10.1111/j.1365-2575.1996.tb00015.x
22. Fakultas Kesehatan Masyarakat Universitas Hasanudin. (2016). *Buku Kurikulum: 8 Kompetensi Sarjana Kesehatan Masyarakat*. Makassar: Universitas Hasanudin.
23. Kementerian Kesehatan RI (2007). *Keputusan Menteri Kesehatan Republik Indonesia tentang Standar Profesi Bidan (Nomor 369/MENKES/SK/III/2007)*. Jakarta: Kementerian Kesehatan RI.