24

Dry-lab experiments with epidemiological data analysis

Andreas Rieckmann

Department of Public Health
University of Copenhagen

Introduction

Health and Informatics graduates work at the intersection of multiple disciplines across health, IT and data science ("Uddannelsesråd for folkesundhedsvidenskaberne. 2018-studieordning for bacheloruddannelsen i sundhed og informatik ved Det Sundhedsvidenskabelige Fakultet ved Københavns Universitet", n.d.). Some graduates will work directly or indirectly with epidemiology ("Bachelor i sundhed og informatik – Københavns Universitet", n.d.), and thus efforts to create deep and long-term learning of epidemiological concepts are essential. Kolb's learning cycle suggests that learning is created through a cyclic sequence and that it is enhanced by using various forms of learning styles (Healey & Jenkins, 2007).

The course on epidemiology for 2nd-semester students at the Health and Informatics Bachelor's programme is a 7.5 ECTS course that aims to enable the course participant to summarize, explain, judge, and criticize scientific papers within the health domain, including calculating and interpreting basic frequency and association measures. The course is structured with lectures and exercises grouped in sets of sequences such that they support the learning outcomes related to frequency and association measures, study designs, biases, the population etiological fraction, and reviews and meta-analyses. Each lecture has a clear set of sub-learning outcomes that is reached through reading material and lectures supported by interactive elements such as quizzes and dialogues. Accompanying exercises consist of sets of questions about an applied epidemiological article, which the students have read in advance of the exercises. All calculations of frequency and association measures can be done using a simple calculator. The course has been continuously developed over many years by previous course leaders. The exam resembles the setup of the exercises, such that the students receive an epidemiological article 24 hours in advance of a 4 hours written exam. For the written exam, the students answer 12 questions related to the article they had read.

Recently, the Health and Informatics Bachelor's and Master's programmes have been revised according to the University of Copenhagen's digitalization strategy of implementing a digital core curriculum in all studies at the Faculty of Health ("Strategic Goals – University of Copenhagen", n.d.). One new element of the epidemiology course is, for example, to know about frequently used statistical models used in epidemiology.

Based on Kolb's learning cycle and with the KU digitalization plan in mind, I intended to complement the epidemiology course with dry-lab experiments with epidemiological data analysis that should allow the course participants to reach a deeper level of understanding of the epidemiological field and its relation to other fields through concrete data-near experiences. The course participants should use the statistical programme R to experience how epidemiological analyses can be conducted for research. It would also allow them to experience how causal data respond to different analytical choices and how bias can be introduced and addressed analytically. It should further allow the course participants to visualize study results. Each theme (a lecture and a two hour article-question-based exercise) would be accompanied by a short R script. The students at Health and Informatics were already taught R at the course Statistics at their first semester. The dry-lab experiments with epidemiological data analysis would bridge their knowledge of statistics and statistical models to epidemiology for analysing real-world health problems.

Thus, the problem statement was:

> Could dry-lab experiments with epidemiological data analysis enhance a deeper level of understanding of the epidemiological field for students at the Bachelor's programme of Health and Informatics?

By discussing this chapter with my departmental supervisor, multiple elements were improved, particularly a new element was added to the discussion about aligning language and exercises in collaboration with the course leader in Statistics to bridge learning across fields even better.

Kolb's learning cycle

Kolb wrote in 1984 that "*Learning is the process whereby knowledge is created through the transformation of experience*." (Healey & Jenkins, 2007) and he suggested a cyclic structure of the curriculum. The cycle consists of four stages each associated with different learning styles to match the style of the learner and the teacher (Healey & Jenkins, 2007). Though learners prefer the learning style that is easiest for them, evidence shows that learning is improved when more learning styles are used (Stice, 1987). The cycle resembles more a spiral where each iteration progress (Healey & Jenkins, 2007) and further several overlapping cycles at different hierarchies can be implemented simultaneously e.g. cycles within lectures, within exercises, and across lectures and exercises through the full course (Healey & Jenkins, 2007). The four sequential stages in the cycle and accompanies learning styles are shown in Table 1.

Table 1. Kolb's learning cycle, stages and learning styles.

Stages	Learning styles
Concrete experience (i.e. the learner is actively experiencing an activity). The students DO.	Accommodators learn by being active and concrete to carrying out experimental plans (linked with Active experimentation too)
	Divergers learn by being reflective and concrete to use many perspectives on a situation to generate ideas
Reflective observation (i.e. the learner reflects on the experience). The students OBSERVE.	Assimilators learn by being reflective and abstract to inductively create theoretical models.
Abstract conceptualization (i.e. the learner conceptualizes a theory of the observed). The students THINK.	Convergers learn by being active and abstract to rely on hypothetical-deductive reasoning
Active experimentation (i.e. the learner plan to test the theory in an upcoming activity). The students PLAN.	Accommodators (linked with Concrete experience too)

Using Kolb's framework, I intended to increase learning through the iterations illustrated in below Figure 1.

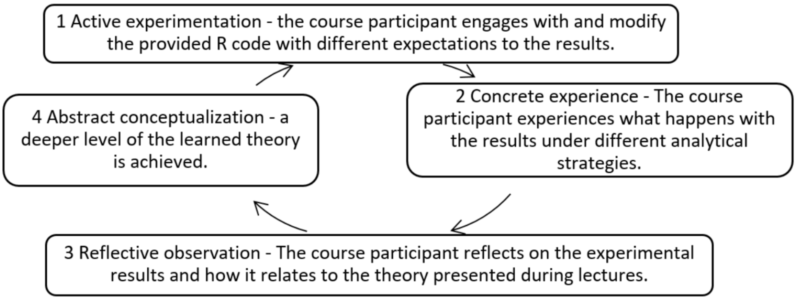

Figure 1. Intended stages of Kolb's learning cycle for the developed course material.

The hope was that the dry-lab experiments with epidemiological data analysis would engage with the exercises in an experimental way, such that they iterate through Kolb's learning cycle first to understand the code and concept, subsequent to change conditions to see how it reflects in the results, and thus pass through the cycle multiple times. For example course participants would experiment and "see" how problems (bias) occur in data, and how to correctly analyse data. This was an element, which could complement the existing course material, and given the profile of the Health and Informatics programmes data-near work seemed as a match for their interests.

Developed course material

For all themes (i.e. lectures), I prepared short commented R scripts that either lacked some code or had questions for the course participants about expectations and understanding of the analytical strategy. The expected learning outcomes of the scripts are shown in Table 2.

Table 2. Expected learning outcomes of the dry-lab experiments with epidemiological data analysis.

Theme	Titles of sets of lectures and exercises	Expected learning outcomes of the dry-lab experiments with epidemiological data analysis
Frequency and association measures	Introduction to epidemiology	To learn how to generate causal data and predict what to expect from causal data using known a well-known statistical model.
	Epidemiological frequency measures	To investigate an empirical data set and judge which kind of association measures as well as calculate it for two sub-groups.
	Association measures	To use the knowledge of generating causal data and analysing association measures using well-known statistical models.
	Effect modification	To use the knowledge of generating causal data and analysing association measures using well-known statistical models for interactions.
Study designs	Randomized controlled trials	To work with real data from an RCT and to test the independence of the population characteristics with the treatment randomisation.
	Cohort studies	To work with real cohort data and to reconstruct part of a Table 1 of the population characteristics.
	Case-control studies	To use different approaches to analyse a case-control toy example.
	Other study designs	To analyse a toy example illustrating an ecological fallacy.
Intern validity	Confounding	To causally generate data and analyse it using different strategies to illustrate that we can estimate the causal difference by adjusting the well-known statistical model.
	Selection bias	To illustrate the impact of selection in a causal setup.
	Measurement bias	To illustrate the impact of measurement bias in a causal set-up.
Public health potential	Population aetiological fraction	To use a causal generation of data to calculate the population aetiological fraction (PAF), and to allow the user to change basic parameters to see the impact on PAF.
External validity	Reviews and meta-analyses	Using an R package to create forest plots and meta-estimates for several study results.

Below, I present one example from the theme of Confounding, which I also actively used in one of the lectures.

Box 1. R script for the theme of Confounding.

```
# Epidemiologi, 2022
# Lektion 9 - Confounding
# Vi vil gerne simulere en studiepopulation på [n]
n = 100000
# Vores confounder har en prævalens på [pC]
pC = 0.3
# Vi genererer nu en vektor C.
C = rbinom(n,size=1,prob=pC)
mean(C) # Det kan vi tjekke her ved at få gennemsnittet
# Vores interesseeksponering har en prævalens på [pA]
pA = 0.2
rd_CA= 0.2 # RD for confounder på eksponering
# Vi genererer nu en vektor A.
A = rbinom(n,size=1,prob=pA+rd_CA*C)
mean(A) # Det kan vi tjekke her ved at få gennemsnittet
mean(A[C==1]) # Gennemsnit hvor C er 1
mean(A[C==0]) # Gennemsnit hvor C er 0
21 # Vores udfald har en prævalens på [pY]
pY = 0.001
rd_CY= 0.2 # RD for confounder på udfald
rd_AY= 0.1 # RD for eksponering på udfald
# Vi genererer nu en vektor Y.
Y = rbinom(n,size=1,prob=pY + rd_CY * C + rd_AY * A)
mean(Y) # Det kan vi tjekke her ved at få gennemsnittet
mean(Y[A==1 & C==0]) - mean(Y[A==0 & C==0]) # Effekt af A inden for strata af C == 0
mean(Y[A==1 & C==1]) - mean(Y[A==0 & C==1]) # Effekt af A inden for strata af C == 1
############################################
# Fra hvilken linje i koden kan vi se hvad vi skulle have forventet angående effekten af A på Y
############################################
# Vi samler disse i et datasæt og rydder op
data <- data.frame(C,A,Y)
rm(list=setdiff(ls(), "data"))
# Se at det ser rigtigt ud
View(data)
############################################
# Hvad får vi hvis vi blot ser på associationen mellem A og Y? [hint prøv lm(Y ~ A, data = data)]
############################################
# Kan vi justere vores model for confounding?
############################################
```

It followed 5 steps: 1) Generate causal data with confounding, 2) Discuss the data generating structure, 3) Experience what happens when data is analysed without accounting for confounding, 4) Expect what happens when adjusting for confounding, 5) Experience what happens when data is analysed accounting for confounding. The R script (in Danish) is shown below in Box 1 and an accompanying graph used in teaching is in Appendix A.

Implementation

When I introduced the course, I also introduced that we were experimenting with a new complementary learning part – Dry-lab experiments with epidemiological data analysis. That this learning material was supposed to give them an understanding of applying epidemiological thinking to data analysis. I finally said – to which I regret – that it was not mandatory.

At the first number of lectures, I asked the students about their opinion of the R scripts, and I understood that few used it. At Health and Informatics, courses are evaluated formally every two years, and this year there were no formal evaluation. I, however, conducted two evaluations – a midterm and a final evaluation – where the students responded to a short quantitative session (see the Figure 2, A and B) of whether they were satisfied with the difficulties of the course material, the lectures, the exercises, communication. And whether they used the R scripts and whether they were useful. We then followed it up with a dialogue. It was clearly indicated at the mid-term evaluation that the dry-lab experiments with epidemiological data analysis had little uptake among the course participants (Figure 2, A). Based on the dialogue with the students, my understanding was that the far majority did not use it. After the midterm evaluation, I discussing this with my departmental and pedagogical supervisors, and we decided to include some of it as part in the lectures. It turned out, however, to take up much of the lectures.

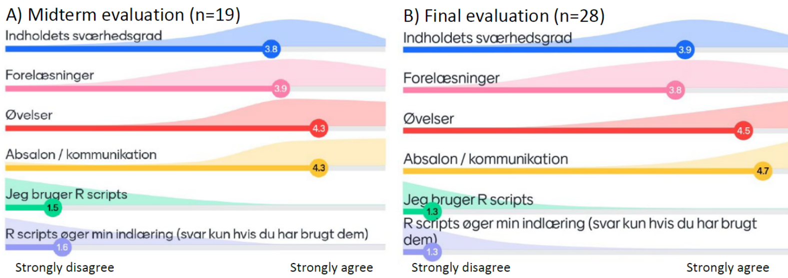

Figure 2. Responses to: "I am satisfied with…".

At the final evaluation, I used the same questions as for the midterm evaluation (Figure 2, B) and again followed with a dialogue about which areas to keep and which to improve. I already knew that the R scripts were not priorities. The students told me that the idea of the R scripts was good, but should be revised. Some students wished for more lectures and discussions, and they all valued the ordinary article-question-based exercises. They found the course nicely aligned with their previous statistics course ("Own notes from the final evaluation", 2022).

Discussion

There was a rationale behind the dry-lab experiments with epidemiological data analysis and it complements the existing learning material both in relation to learning style and in relation to the digitalization strategy. The dry-lab experiments with epidemiological data analysis, however, did not succeed to become prioritized by the students.

Previous studies have investigated explanations for students not prioritizing work in relation to attending class, and several explanations may be transportable to understanding why the course participants did not prioritise the dry-lab experiments with epidemiological data analysis and potentially lead to a solution to improve its prioritization.

Ulriksen and Nejrup pointed out several points related to how students perceive the relevance of teaching and course materials. For example, students that "*did not experience the teaching as relevant for their study or if they experienced a lack of coherence between the teaching and other* *parts of the programme they might decide to skip class.*" (Ulriksen & Nejrup, n.d.). The course participants in my course may have experienced the dry-lab experiments with epidemiological data analysis lacking coherence with the rest of the course material. Ulriksen and Nejrup further found that "*Some of the students also considered whether the teaching would offer them anything they could not as well get from reading the books*." (Ulriksen & Nejrup, n.d.). Likewise, the course participants in my course may have found the existing course material sufficient, despite that the dry-lab experiments with epidemiological data analysis were bridging material they had not had bridged in any existing course material. Also, Ulriksen and Nejrup found that "… *some differences between programmes related to the students' sense of relevance that had to do with the perspective of the programme and the nature of the competences developed there*." (Ulriksen & Nejrup, n.d.), which could have increased the interest of the course participants interested in working in research. Retrospectively reflecting on the introduction of the course, one should not introduce course material as non-mandatory.

Several observations by Ulriksen and Nejrup highlighted the link between students' prioritizations with their expectations of the exam. For example, "[the interviewed students'] *study activities were to some extent focused on what was required at the exam*." (Ulriksen & Nejrup, n.d.). The lack of using the R code for the exam may have been an explanation for the lacking uptake. The focus on exams has been highlighted in other studies of students' use of time, where "*Some students would skip reading and focus on exercises, if they believed that to be the best preparation for the exam*" (Ulriksen & Nejrup, 2020). Based on the evaluations, the course participants too valued the ordinary article-question-based exercises. Other studies have also indicated students focus on exams from day one of the courses (Nielsen & Ulriksen, 2021). For future changes, assessing the congruence of the course and ensuring an alignment between dry-lab experiments with epidemiological data analysis and the exam may likely improve how it is prioritised.

Studies have pointed out how students work during a course, such as: "*Consequently, they did some reading during the semester, but the bulk of their work was when preparing for the exam*." (Ulriksen & Nejrup, n.d.). The course participants at my course may likewise have focussed on the "mandatory" parts during the course, and as it takes additional efforts to read and work in R, there may not have been time to work on the dry-lab experiments with epidemiological data analysis eventually.

Finally, Ulriksen and Nejrup found that "*Students also emphasised the relation to the teacher as important for their inclination to putting in effort into a course*." (Ulriksen & Nejrup, n.d.). This is an explanation that cannot be ruled out, however, the relation to the students seemed to be good with a nice dialogue throughout the course, which was also reflected in the overall evaluation of the course.

When discussing this chapter with my departmental supervisor, Mads Kamper-Jørgensen, who have incorporated similar data-near exercises using R for course participants in Epidemiology at the Public Health programme, he mentioned that it was especially successful because he and the course leader on Statistics had aligned both language and exercises, such that the cross-disciplinary learning was bridged even better. A way forward to improve the dry-lab experiments with epidemiological data analysis at Health and Informatics would be to collaborate more with their course leader in Statistics. Mads further pointed out that it may pay off to focus on a fundamental level of learning and increase the time spent on ensuring the course participants understanding of these elements rather than covering many points. This is particularly important as these exercises were intended to partly build upon each other.

Conclusion

Based on Kolb's learning cycle, the developed material as part of this university pedagogy project – Dry-lab experiments with epidemiological data analysis – has potential. Unfortunately, the uptake was close to none. Based on previous studies on students' time allocation, improving the course participants' prioritisation of this course material, a better alignment of the course and especially exam may be key, such that they are not perceived as non-mandatory. Also, collaboration with other course leaders for bridged learning should be pursued. This added data-near and course bridging material may improve learning in introductory epidemiology courses – both for short and long-term outcomes related to the course participants' engagement and understanding of the field of epidemiology.

References

Bachelor i sundhed og informatik – københavns universitet. (n.d.). https://studier.ku.dk/bachelor/sundhed-og-informatik/

Healey, M., & Jenkins, A. (2007). Kolb's experiential learning theory and its application in geography in higher education. http://dx.doi.org/10.1080/00221340008978967

Nielsen, K., & Ulriksen, L. (2021). Following rhythms and changing pace–students' strategies in relation to time in higher education. *Teach. High. Educ*, *1–15*.

Own notes from the final evaluation. (2022, April 26).

Stice, J. E. (1987). Using kolb's learning cycle to improve student learning. *Engineering education*, *77*(5), 291–96.

Strategic goals – university of copenhagen. (n.d.). https://sund.ku.dk/uddannelse/for-studerende/studieordninger/itog-sundhed/Sundhed-informatik_BA_2018_2022-23.pdf

Uddannelsesråd for folkesundhedsvidenskaberne. 2018-studieordning for bacheloruddannelsen i sundhed og informatik ved det sundhedsvidenskabelige fakultet ved københavns universitet. (n.d.). https://sund.ku.dk/uddannelse/for-studerende/studieordninger/itog-sundhed/Sundhed-informatik_BA_2018_2022-23.pdf

Ulriksen, L., & Nejrup, C. (n.d.). Students' time budget practices: This was the time of our lives.

Ulriksen, L., & Nejrup, C. (2020). Balancing time – university students' study practices and policy perceptions of time. https://doi.org/10.1177/1360780420957036

A - Graph supporting the dry-lab experiments with epidemiological data analysis on confounding