Investigation of student reasoning skills about flow processes in logistics
(Short Paper)

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ABSTRACT

We present preliminary results of a pilot study investigating the reasoning skills of students in logistics and mobility in the context of hydrodynamics. Particularly, we were interested in the students’ thinking of parcel flow in logistics and steady-state pipe flow. Our goal was to investigate if students of logistics would show more, less, the same, or different misconceptions commonly found in students confronted with hydrodynamics problems. We hypothesize that, due to their exposure to flow-like systems (transport chains, band conveyors, hub systems etc.), students develop a certain intuition about flow processes.

Interviews were held with several students that attended “Transportation and Handling Technology” at Hamburg University of Technology (TUHH) in the two winter semesters of 2020/2021 and 2021/2022.

We found that half of the students were unable to solve questions regarding the parcel flow on a band conveyer or the steady-state flow in a narrowed pipe, while the other half of the participants showed the correct understanding of flow processes to solve all the problems. We present evidence that misconceptions about hydrodynamics strongly affected participants’ ability to solve logistics problems. We also discuss the application of our findings for instruction in logistics.

1 INTRODUCTION

In their studies and later careers, students of logistics are confronted with a variety of flow processes, such as transportation on band conveyors, supply chains, hub systems and material transport in mines, factories and harbours. Based on this, we raise the question if these students obtain a certain intuition about the continuity concept. This encompasses the laws of flow processes, mainly the idea that material cannot be lost which leads to various conditions for possible flows.

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Continuity and flow are usually discussed in physics in the context of hydrodynamics, but students of logistics have rarely contact with a formal education in this field. Therefore, we designed several related questions in logistics and hydrodynamic to shed light on the following research questions:

\[ \text{A) Do students of logistics have any intuition about flow processes and can they transfer these insights in order to solve problems of hydrodynamics?} \]
\[ \text{B) What are their thought processes and possible misconceptions when confronted with these problems?} \]

We know that hydrodynamics problems are often difficult to solve for students of various fields. Whereas this problem is known and relatively well documented for students of physics and engineering ([1],[2],[3]) few studies have been conducted on the intuition and reasoning skills in students of logistics. Therefore, we are not only interested in the existence of an intuition about the continuity concept, but also in misconceptions the students might have if they lack this intuition. Such insight into students’ ideas may help design better instruction for the field of logistics where flow processes play an important role. There have been several studies concerned with knowledge and skill transfer between known concepts and novel situations [4]. This cognitive ability is troublesome and difficult [5]. Though there are many psychological and didactical models to understand transfer, these lie outside the scope of this paper. For now, we are focusing on observing transfer (or the lack thereof) and will postpone the discussion of appropriate cognitive models to a later point in time.

2 METHODOLOGY

We conducted interviews in January and February of 2022 with four bachelor students who had attended the lecture “Transport and Handling Technology” in the winter semester of either 2020/21 or 2021/22. All students had attended introductory mechanics and math courses but none had had any instruction in fluid mechanics. This makes for an interesting background because we can assume that their intuition about fluid dynamics either stems from logistics or day to day intuition and not formalized education in these fields. Here we present and discuss two of the four items that had been given to the students. These two items yielded the most interesting responses and give a first look into the understanding of flow processes in the participants.

| Question 1 |
| "Two band conveyors (A and B) are serially-connected and are packed with small parcels that are separated by a long distance compared to their own size. At the end of A the parcels fall on band conveyor B and both band conveyors operate with the same speed. Due to a malfunction, the speed of band conveyor B must be reduced by half of its original speed. After a long time, does the delivery rate increase, decrease or stay the same?"

Our expected answer is that the delivery rate stays the same. While the velocity of band conveyor B is halved, the parcel density is doubled. Therefore, the delivery rate stays the same, except for the time the less densely packed parcels need to reach the point where the delivery rate is measured. However, since we want to look at a steady state, students are asked to consider the delivery rate “after a long time”.

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In this question, the parcel flow behaves like a compressible steady state flow. We wanted to see, if students could make this (or another helpful) connection to solve the problem.

### Question II

In the following drawing, we can observe a liquid flowing through a pipe. At one point the pipe narrows. Which statements can be made about the volume flow and the velocity of the liquid? Explain your reasoning.

This is one of the many variants of a common hydrodynamics problem. As in question (I), the volume flow stays constant; for an incompressible fluid, however, this means, that the velocity must increase.

### 3. RESULTS

Two of the participants had little to no problems solving the tasks. The other two struggled and revealed some misconceptions about the topic. We will focus on Participant 2 and 3, who did show misconceptions in their rationale.

#### 3.1 Question I: Failure to see or ignoring the density change

In question (I) the misconception we anticipated is that students might think that it is imperative for the delivery rate to go down after the second band conveyor goes to half its original speed. This misconception is presented well in the following statement from participant 2:

“The delivery rate is of course reduced because the velocity is reduced by half. This means the delivery rate is also reduced by half.”

Interestingly, participant 2 did realize that the space between parcels must be smaller:

“The same amount [of parcels] reaches the end but later...or slower with a smaller space in between.”

While participant 2 realized conservation of parcels as well as the decreased space between parcels, they did not see a connection to the delivery rate. Participant 3 had similar problems, even though imagining two identical set ups (1 and 2) next to each other but with one band conveyor system (1) running without malfunction (A1 and B1 have the same speed.). While they may have realized that the parcels move slower on B2 but with a higher density compared to the unthrottled system they still arrived at the wrong conclusion:

“The delivery rate of band conveyor 1 would be of course greater.”
3.2 Question II: Inferring lower flow rate because of decreased diameter

In question (II) we saw similar reasoning. Both participants argued that the volume flow must be smaller due to smaller volume in region B. Participant 2 stated about the volume flow:

“Of course, the volume in A is much larger than in B. (…) Naturally this leads to a jam and the velocity is lower in B.”

Here, the use of the term “jam” even hints at some form of compressibility. According to participant 2, liquid must backlog at the narrowing. While both first stated that the velocity must therefore decrease, Participant 3 later changed their mind and argued:

“Either the velocity stays the same and the flow decreases or the volume flow stays the same and the velocity increases.”

But they finally decided on the wrong conclusion:

“The volume flow is decreased because if the pipe is smaller, less liquid can fit inside.”

We found that the relation between velocity, density and delivery rate/volume flow is not clear for these students.

4. INTERPRETATION

Though small, the study showed interesting results. Half of the students could solve all questions with ease, the other half showed common misconceptions about flow processes. This suggests that we can indeed expect a certain level of intuition about hydrodynamics from students of logistics. On the other hand, the results also indicate that some students have similar struggles as other populations and their misconceptions are related to the idea of continuity. At this point we can only speculate about the exact mechanism that leads to these misconceptions. Both questions are very similar in design. The difference lies in the variables that are fixed by the scenario and the variables that depend on these. For question (I) it is the velocity that is changed through the malfunction. This leads to an increase in density so that the delivery rate ultimately stays the same. The compressibility adjusts for the reduction in velocity. In question II the change in velocity is the result of a disturbance (narrowing), not the disturbance itself. But since the density cannot change, the velocity must increase. In either case the flow rate stays the same. One could argue that the students have the same intuition about both problems: that a change in velocity must lead to a change in flow rate. In both scenarios, compressibility and its implications are not well understood. In question (II) students failed to see the incompressibility therefore concluding that the flow rate must decrease. In question (I) they recognize the compressibility but do not see its implication for the (unchanged) flowrate. Interestingly, the conservation of mass seems to be clear. The liquid in question (II) cannot disappear, therefore there must be a jam at the narrowing, participant 2 argued. This is, in this mind set, a logical conclusion. The concept of continuity...
seems to be understood to some extent but it cannot be brought to its practical and logical conclusion.

Question (I) might reveal a certain confusion about the steady state character of the problem. Future questions might adjust for that by rephrasing the problem in terms of comparison of two time independent situations. Further study is needed to pinpoint the exact mechanism of these misconceptions. The results encourage us to look further into the reasons why some students of logistics seem to be able to handle hydrodynamics problems well and how this transfer of intuition, and its failure, works.

During the upcoming semester, we plan to interview more students of logistics to get a broader picture of their reasoning skills.

Our findings suggest an early and focused treatment of flow processes in logistics education, with a special emphasis on the underlying principles of continuity and (in)compressibility.

Since the first submission of this paper, six more interviews were conducted. These showed similar results and opened up a deeper view of the subject. The combined results could not be submitted in this paper, but will be discussed in the presentation of our work at the SEFI Annual Conference in 2022.

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