USE OF GRAVITY CURRENT VIDEOS AS A MODEL FOR BETTER UNDERSTANDING OF UNIFORM MOTION

Tjipto Prastowo[1], **Muhammad Nurul Fahmi[2]**, **Arie Realita[3]**, **Muhammad Habibulloh[4]**
Fakultas Matematika dan Ilmu Pengetahuan Alam, Universitas Negeri Surabaya[1,2,3,4]
e-mail: tjiptoprastowo@unesa.ac.id

ABSTRAK

Siswa sekolah menengah atas belajar tentang gerak lurus beraturan secara teori di kelas melalui pemahaman konsep gerak lurus beraturan dan aktivitas praktikum fisika di laboratorium. Mahasiswa perguruan tinggi juga mendapatkan perlakuan dan pengalaman belajar yang sama tanpa ada kajian mendalam tentang contoh nyata gerak lurus beraturan. Dalam jangka panjang, pengalaman belajar seperti itu bisa menimbulkan masalah kesulitan belajar tentang pemahaman gerak lurus beraturan jika mereka menemui contoh-contoh nyata gerak lurus beraturan dalam kehidupan sehari-hari. Tujuan penelitian pengabdian masyarakat ini ada dua, yaitu pertama melibatkan 15 orang guru fisika sekolah menengah atas untuk mengamati gerak *gravity current* sebagai model gerak lurus beraturan melalui pendekatan pembelajaran berbasis video dan kedua memfasilitasi para guru tersebut melalui keterlibatan aktif selamat proses pengamatan untuk pengayaan konsep gerak lurus beraturan. Metode penelitian dilaksanakan melalui serangkaian pengamatan video *gravity current* untuk mempelajari gerak lurus beraturan dan tes diagnostik yang dirancang untuk pengayaaan konsep gerak lurus beraturan. Hasil-hasil tes diagnostik menunjukkan bahwa pemahaman para guru tentang konsep gerak lurus beraturan adalah baik meskipun mereka harus belajar melalui pembelajaran berbasis video yang baru diperkenalkan. Pendekatan pembelajaran dengan media video mampu meningkatkan gairah dan hasil belajar yang ditunjukkan dengan hasil tes diagnostik yang relatif baik. Implikasi proses belajar dengan memanfaatkan video pembelajaran dalam penelitian ini adalah peningkatan pemahaman konsep gerak lurus beraturan yang bisa diterapkan untuk menunjang pengajaran fisika di sekolah.
Kata Kunci: *Gravity Current*, *Gerak Lurus Beraturan*, *Pembelajaran Berbasis Video*

ABSTRACT

Secondary school students learn about uniform motion from their physics teachers through either an introductory concept of motion, particularly uniform motion in class or hands-on activities in the laboratory. In the university, students obtain similar treatment with no insight into the best example of uniform motion. In the long term, this may result in learning difficulties when facing real examples in nature. The objectives of this study are two-fold. We first engage 15 high-school physics teachers to observe horizontal motion of fluids with different densities as a model for uniform motion through an approach of video-based learning. We then facilitate them through active engagement during the observations to enrich teachers' pre-conception of uniform motion. The methods in this study involved watching gravity current videos to examine its propagation and delivering a diagnostic test, designed for enrichment processes. The results showed that overall understandings of the gravity current motions were relatively good amongst the participants despite the newly instructional videos. The approach led to enhanced learning, where good performance on the test was achieved. In turn, the gained understandings could be implemented and used to support goals of better quality of physics teaching in schools through sustainable development of human resources.
Keywords: *Gravity Current*, *Uniform Motion*, *Video-Based Learning*

INTRODUCTION

Gravity current is a horizontal bi-directional flow of fluids of different densities that may occur in many geophysical contexts from small to large scales (Benjamin, 1968; Simpson, 1997). In the laboratory, this type of flow can be modelled using a horizontal long tank divided by a vertical sliding barrier placed in the middle and filled with two fluids of different densities (Prastowo, 2009; Linden, 2012; Longo et al., 2016; Ahmed, 2017; Tjung & Kickert, 2025). The resulting configuration is simply illustrated in Fig. 1 below.
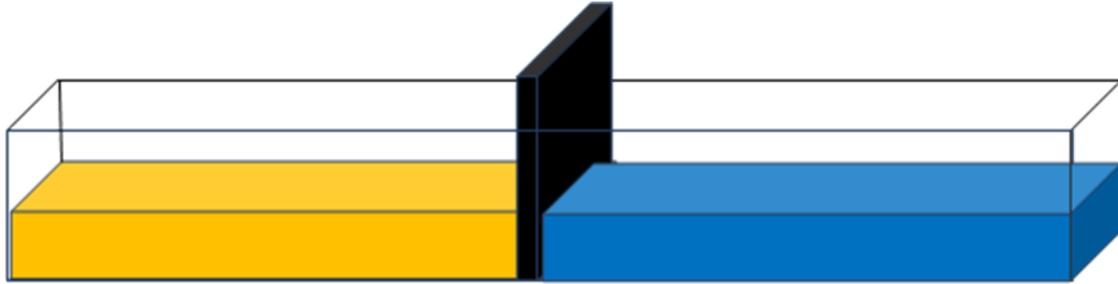

Figure 1. A horizontal long tank utilised to facilitate gravity current experiments, here featuring the sliding barrier in black, a fluid of high density in blue and another fluid of low density in yellow so as to create horizontal density difference across the barrier

When the barrier is removed, two opposing gravity currents are set up in motion, where the dense current moves steadily at constant speed to the left along the tank base (uniform motion) and the less dense current propagates in the same manner to the right near the surface. Previous work on gravity currents (Shin et al., 2004; Prastowo, 2009; Linden, 2012; Ahmed, 2017; Cafaro & Rooney, 2018; Zordan et al., 2018; Ikeda & Testik, 2021; Kokkinos & Prinos, 2022) claimed that these currents move at speed v, calculated from

$$v \propto c\sqrt{g'h} \tag{1}$$

where $g' = g\Delta\rho/\rho_o$ is a reduced gravity, g is a gravitational acceleration (9.8 ms^{-2}), $\Delta\rho$ is a density difference between the fluids, ρ_o is a reference density and h is a free surface height. The proportionality in Eq. (1) becomes an equation when a multiplication factor c is replaced with an arbitrary number of less than 0.5 (depending on the experimental set up and types of gravity current, either in the laboratory or numerical simulations).

In this context, the density difference $\Delta\rho$ sets up horizontal pressure gradient Δp that provides an internal driving force for the horizontal motions of the opposing gravity currents, in addition to an external driving force, derived from the surface height difference between two points measured from the base, if any. The pressure gradient is given by

$$\Delta p = \rho g\,\Delta h + gh\,\Delta\rho \tag{2}$$

Assuming that there is no difference in the free surface heights of the fluids in the channel (see Fig. 1), or mathematically $\Delta h = 0$, we then have

$$\Delta p = gh\,\Delta\rho \tag{3}$$

for the only driving force working on the currents. This is the essence of gravity currents, showing that the $\Delta\rho$ causes the fluids to flow in the channel. The important point to note is that the dense current (blue) and less dense current (yellow) move at constant speed, depending on the initial heights. When the heights are the same, the governing equation for the flow is given by Eq. (3) and the speed is estimated from Eq. (1). It follows that gravity current experiments and the corresponding videos could potentially be used as a good model for uniform motion in the laboratory scale (Prastowo, 2009). The videos could then be demonstrated in class to support video-based learning for an enrichment process with active engagement from participants

(Brame, 2017; Ruf et al., 2023): mid-year students or pre-service teachers in the university or even teachers in schools.

In many situations and normal learning environment, secondary school students learn about uniform motion from their physics teachers through either an introductory concept of motion in class or hands-on activities in the laboratory. In the university, students obtain similar treatment, providing no insight into the best example of uniform motion. In the long term, such learning experience may result in learning difficulties when facing real examples. That is why we here use gravity current videos for better understanding of uniform motion. In the videos, participants may notice that, in the absence of the Δh, the dense current remains observed, implying a learning problem of cognitive conflict (Rahim et al., 2015; Mufit et al., 2019; Parwati & Suharta, 2020; Mufit et al., 2023).

The aims of this study are therefore two-fold. Firstly, we involve teachers to observe the horizontal motion of fluids with different densities as a model for uniform motion through an approach of video-based learning. Secondly, we facilitate through active engagement during observations to enrich teachers' pre-conception of uniform motion. The methods developed involved visual observations of gravity current videos to examine its propagation and delivering a diagnostic test, specifically designed to identify basic understanding of the uniform motion for the enrichment process in a relatively new learning environment using instructional learning videos on gravity currents. These are expected to support goals of better quality and hence improvement of physics teaching in schools and universities through sustained learning over time for the teachers, relevant to item 4 of sustainable development goals (SDGs), available at https://www.undp.org/sustainable-development-goals.

METHODS

The horizontal long tank for performing gravity current experiments has already been available for two different sizes in Physics Department, The State University of Surabaya, where the total length is 2 m, height is 20 cm, and widths are 10 cm and 20 cm (see Fig. 1). Although the tank was ready for use but its sizes and fragility to be broken apart made it difficult to bring from one place to another even only for within walking distance. That was why we filmed a series of gravity current experiments for capturing the essence of uniform motion of the flow. The recorded files in video clips could potentially be used to effectively demonstrate a 'real example' of uniform motion at constant speed in the laboratory. Detailed procedure for the experiments is not here provided for maintaining simplicity. However, flow general description recorded in clips and particularly use of such clips to effectively model uniform motion of constant speed in nature (even for small scales only) are, to better suit the problem of video-enhanced learning, breakthrough for activities in a community service program, held for all participants coming from 15 high-school physics teachers from different places around Kabupaten Tuban, a small town in East Java.

SMAN 1 Plumpang, Kabupaten Tuban served as a host for the meeting (offline) upon 18 March 2024, where all the participants or respondents joined in class to observe a series of videos on the gravity currents. The following activity was something like homework, individually performed within an amount of time allocated (about a week, considering that they all had jobs to do in schools); it was a further analysis of the videos at homes (clips or videos were demonstrated and distributed at the meeting).

During the meeting, a four-tier diagnostic test was distributed for preliminary exercise, where a sampled question is shown in Fig. 2. After this test was finished, there came videos on gravity currents with varying density differences to be demonstrated in class.

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Untuk mempermudah pengamatan saat percobaan *gravity current* berlangsung, larutan garam diberi zat pewarna biru dan air tawar diberi zat pewarna kuning. Kemudian ditempelkan 'kertas jejak' pada bagian dinding depan tangki dan diletakkan proyektor untuk sumber pencahayaan pada bagian belakang tangki. Apabila penyekat dibuka, menurut pengetahuan anda apakah yang akan terjadi pada sistem dua fluida dalam tangki tersebut ?
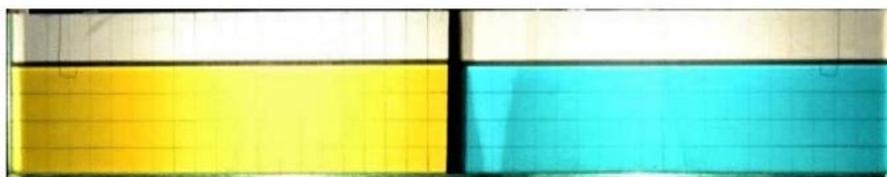
A. Kedua jenis fluida diam dan tidak bercampur.
B. Kedua jenis fluida bercampur secara acak.
C. Terjadi aliran fluida dalam satu arah.
D. Terjadi aliran fluida dalam dua arah.

Figure 2. A sampled question of a four-tier diagnostic test as part of class activity before watching gravity current videos.

Apart from the video demonstrations and diagnostic test, all the participants were asked for filling an individual questionnaire, consisting of questions on how they, that is, each participant, responded educational issues related to video-assisted learning on gravity currents to learn about uniform motion.

RESULTS AND DISCUSSIONS

The results and corresponding discussions are here reported in separate sections, where all the results come first then subsequently followed by the discussions. In each, the following topics are consecutively provided: observational data obtained from the gravity current videos, the diagnostic test and responses from the participants, particularly use of the videos to widen physics teachers' knowledge and strengthen their competence in physics teaching.

Results

Having observed gravity current videos in clips, participants were divided into a group of 3 members, regardless gender with no bias information collected. Each group was facilitated to work from homes using clips of a series of gravity current experiments with varying density differences distributed over class attendance. A week later, the groups reported their analysis of the distributed clips. Here, we sample the best analysis given by a selected group taking from a clip of a gravity current experiment with 2% density difference and the initial surface height of 20 cm (see Table 1). We noted that other reports by other groups were similar to each other, with the difference amongst quantitative results was unimportant (as long as qualitative results were correct) as the primary goal was to observe and find moving objects at constant speed, hence being a good example of uniform motion. Notice that in each clip gravity currents are divided into two opposing currents, namely the dense current propagating along the bottom of the tank and the less dense current advancing near the surface. These currents were differently coloured (see again Fig. 1 and Fig. 2) to help visualise for clear observations in each experiment. It is then understood that slighly different travel times were recorded for each current after travelling the same distance from the midpoint of the tank.

Table 1. The observational data derived from gravity current videos.

No	Travel distance (cm)	Travel time for dense current (s)	Travel time for less dense current (s)
1	10	1.28	1.25
2	20	2.56	2.50
3	30	3.68	3.60
4	40	4.94	4.85
5	50	6.00	5.90
6	60	6.84	6.70
7	70	7.71	7.55
8	80	8.91	8.75
9	90	10.08	9.90
10	100	11.52	11.30

Before video observations were performed in class, a four-tier diagnostic test (written as Problems 1 to 4) was given for each participant to complete. We present here all the results for the diagnostic test in Table 2. For a further analysis, we provide data for all participants' performance on the test in coded numbers, 0 and 1 (explained later in Discussions).

Table 2. Data for a solution-problem feature from the diagnostic test.

Partisipant	Problem 1	Problem 2	Problem 3	Problem 4
1	1	1	1	1
2	1	1	1	1
3	1	1	1	1
4	1	1	1	1
5	0	1	0	1
6	1	1	1	1
7	1	1	1	1
8	1	1	1	1
9	1	1	1	1
10	1	1	1	1
11	1	1	1	1
12	1	1	1	1
13	1	1	1	1
14	1	1	1	1
15	1	1	1	1

Responses from the participants were also measured during class through questionnaire distribution. A questionnaire containing several questions was distributed over the participants for feedback, asking them to assess some issues related to keynote speaker's performance on delivering learning materials, quality of a diagnostic test, learning activity through videos on gravity currents, effects of video-enhanced learning on ability to do science and misconception reduction. Assessment of such issues were performed on a Likert scale of 1-5, where a given assessment of 1 refers to 'not good', 2 means 'less good', 3 indicates 'fairly good', 4 is for 'good' and 5 is equal to 'very good'. These scales are commonly used in research questionnaires (see, for example, Derrick & White, 2017; Koo & Yang, 2025).

However, it is surprisingly enough to find all the participants assess a set of questions given in the same manner in the sense that they only used scales of 4 and 5 to all the questions with no exception (see Fig. 3).
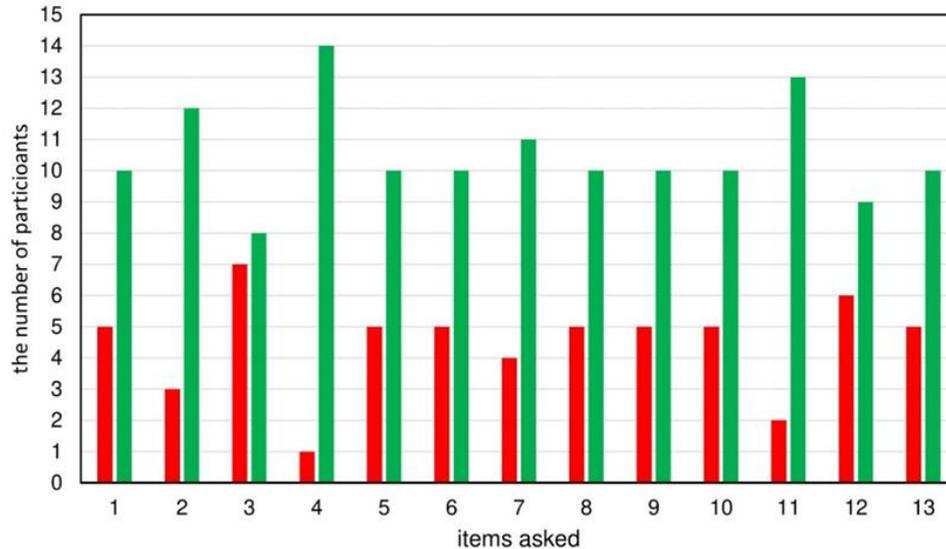

Figure 3. Bar diagrams, showing all participants' responses to video-enhanced learning on gravity currents as a model for uniform motion, where red bars represent 'good' and green bars refers to 'very good' assessments.

Discussions

The numerical data listed in Table 1 provide no significant information associated with the dynamics of the dense and less dense gravity currents unless we change them visually into a single graph for each current. We then convert the data in Table 1 into graphs (see Fig. 4), using spreadsheets to show that both the dense (blue dots) and less dense (red dots) currents move at constant speeds with slightly different values.
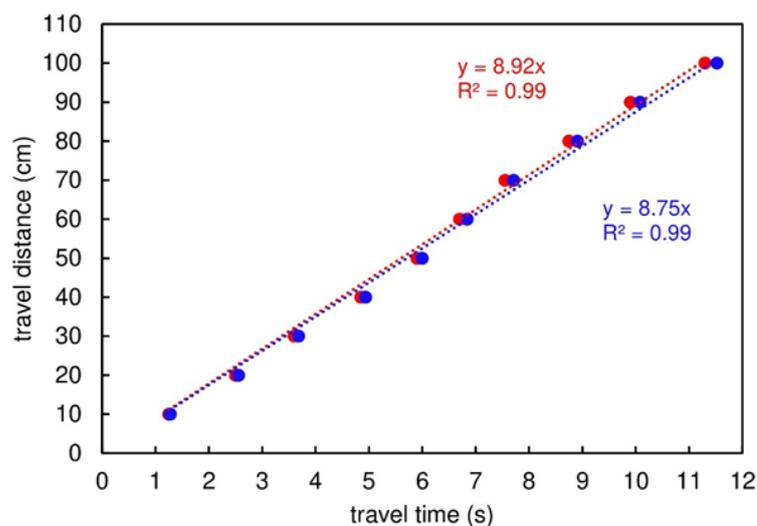

Figure 4. Graphs, describing two opposing gravity currents move at constant speeds, where blue dots represent the dense current advancing along the base of the tank under the influence of bottom friction and red dots represent the less dense current propagating near the surface with relatively minor friction.

It is clear from a regression line passing through blue dots in Fig. 4 that the dense current moves at 8.75 cms^{-1} while another line passing through red dots indicates the less dense current speeding slightly faster at 8.92 cms^{-1} due to relatively minor friction from the surface, compared to bottom friction from the base given to the dense current. The graphs follow straight lines (with high confidence as the coefficient of correlation approaches to one for each graph) with slightly different slopes, as expected, and that both the currents are in uniform motion, in good agreement with the results of previous work (Shin et al., 2004; Prastowo, 2009; Linden, 2012; Tjung & Kickert, 2025). It suggests that the use of experimental videos on gravity currents to model moving objects of constant speed is confirmed in this study.

All the results for the diagnostic test were already listed in Table 2 and we here discuss participants' performance on the test in coded numbers. The diagnostic test consists of a set of questions designed to identify the level of understanding of gravity current motions. The data in Table 2 are given in terms of numbers, 0 and 1, where each has its own meaning. For example, in Problem 1 an entry '0' means that the definitive solution to a given question in the test is considered wrong while '1' shows a reverse meaning. Based on the certainty of response index (CRI) proposed by Hasan et al. (1999), the sets '0' in Problem 2 (if any) are answers with uncertainty and '1' refers to those with confidence when answering Problem 1. For reasoning given to Problem 3, the '0' means weak or wrong reasons written by participants and '1' are for strong or correct reasons. Again, based on the CRI, '0' in Problem 4 indicates answers with uncertainty in solving Problem 3 and '1' are for those with high certainty.

Note that Participant 5 has different answers amongst the participants. Such an answer (0 1 0 1) refers to misconception while others (1 1 1 1) mean a good level of pre-conception of fluid flow governing gravity currents. This leads to a definite conclusion that the videos and corresponding written questions for given problems in class activity are considered not good instrument to detect any misconception. Rather, they are more suitable for and part of the tools for learning enrichment processes (Benkada & Moccozet, 2017; Brame, 2017; Ruf et al., 2023), in relation to the use of recorded gravity current experiments on the videos as a good model for uniform motion in the present study.

It is obvious from Fig. 3 that very good assessments (seen in green bars) are dominant over good ones (seen in red bars). In all aspects, more than half participants are feeling confident with their individual perspectives on five items asked during the observations. In addition, significant contributions to the enrichment process were ultimately observed in the meeting, where the majority were satisfied or even more with the speaker's explanatory performance (in relation to improved understanding of uniform motion), the test quality, learning environment through active engagement throughout the course, improved ability to do science using video-assisted learning, and reduced misconception. All the findings in the present study are found to be in good agreement with previous results of relevant work (Benkada & Moccozet, 2017; Brame, 2017; Ruf et al., 2023), suggesting that new views on the concept of uniform motion are attained and the course is beneficial to all the participants hence considered successful.

Various comments on the use of gravity current videos to model uniform motion are collected aftermath of the course. Here we only provide three of them, useful for feedback for similar treatment to other study groups or similar treatment using different videos made for different learning subjects: (1) The use of learning videos is likely to be effective and efficient to enhance understanding of learning subjects, in particular those requiring a confrontation between facts and ideas in personal mind; (2) The use of learning videos may resolve difficulties when facing with no laboratory to implement hands-on activities; (3) The use of learning videos may solve multiple representation in learning materials found by both students and teachers in class during teaching-learning processes.

CONCLUSIONS

As pointed out throughout the text, the use of gravity current videos to better improve understanding of uniform motion, which is lack of real examples in nature, is effective and efficient. In this context, it is said to be effective because the improved understanding gained by participants is directly obtained while observing such videos and to be efficient because their active engagement of experiential learning through a series of video observations drives high self-motivation into better performance. During the course, feedbacks from the participants may provide insight into possible applications of the methodology to a broader range of learning communities, including different learning environment in the university, for example, where pre-service teachers are studying and preparing for being a teacher. Although this study may be applied to various learning conditions, it is limited with caution as the best performance on it depends on whether there is cognitive conflicts between facts in nature and ideas of learners.

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