Revealing Diversity of Bacillariophyceae in Brantas River through Project Based Learning

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Abstract: Bacillariophyceae is a group of microscopic, unicellular or colonial algae, enclosed within a cell wall made of silica called frustule. Students of the Department of Biology of Universitas Negeri Malang study Bacillariophyceae on the course subject of Thallophyta through the project-based learning method. On project-based learning, students are given a project to identify the Bacillariophyceae found in five streamside observation stations of Brantas River, Malang, Indonesia. The students were grouped into five groups. Each team observed the Bacillariophyceae in a different observation station. This article presents the identification results of Bacillariophyceae found along the Brantas River. There were 84 species of Bacillariophyceae altogether. The number of species found differed in each station, namely 43 species in the 1st station, 70 species in the 2nd station, 34 species in the 3rd station, 53 species in the 4th station, and 41 species in the 5th station. The factors contributing to the different number of species found at each station are still unknown and shall be an interesting field of further research.

Keywords: project-based learning, identify, Bacillariophyceae.

Introduction

Bacillariophyceae is a single-celled or colonial organism. Bacillariophyceae lives in various aquatic environments with sufficient sunlight which can supply the photosynthesis activities to supply marine oxygen concentration¹. Bacillariophyceae is characterized with silica-made cell wall typically made up of two valves which overlap one another like petri dish². The upper valve is called as epitheca while the below valve is called hypotheca³-⁴.

The class of Bacillariophyceae is classified as belonging to Chrysophyta division by Smith and Papenfus⁵. The members of class Bacillariophyceae are known as diatoms. Bacillariophyceae is classified into two orders, i.e. Pennales or Bacillariales and Centrales or Biddulphiales²-⁴. Pennales order consists of four sub-orders⁵ including Araphidineae, Raphidiodineae, Monoraphidineae, and Biraphidineae. Centrales order includes three sub-orders⁶-⁷, namely Coscinoidiceneae, Rhizosoleniineae, and Biddulphiineae.

Bacillariophyceae plays an essential role in marine ecosystem since it is a producer in a food chain which produces organic material for invertebrate⁸-⁹ and it also has a role in the biogeochemical cycle of carbon, nitrogen, phosphor, and silicon, with a significant impact on global climate¹⁰. It also acts as a good indicator to assess the ecological quality of waters for the last fifty years¹¹ since it has a high sensitivity of the physicochemical changes of waters¹².

Bacillariophyceae is one of the topics studied on Thallophyta course subject in Department of Biology, Universitas Negeri Malang. The course goal is, among others, for students to have the skills of taxonomy
concerned with collecting, describing, identifying, and classifying specimens. Such skills can be enabled through project-based learning strategy.

Project-based learning is defined as a learning method which encourages students’ active participation, either individual or group in a certain period to achieve specific products or outcomes relating to real situations in a period of time to cultivate students’ responsibility, discipline, and independence. Project-based learning develops a mastery of 21st Century essential learning since it engages students in designing projects, developing their knowledge, problem solving problem, and their reasoning and communication abilities. The main goal of project-based learning is to assist students to be responsible in their learning process so that they can understand the lesson independently and can produce a specific project either autonomously or collaboratively.

Method

The samples for this research were gathered by the students of the Universitas Negeri Malang who took the Thallophyta course subject with project-based learning strategy. Project-based learning includes three stages, namely project planning (planning), project implementation (creating), and project evaluation (processing).

1. Planning

a. Selection of research area

Brantas River selected as the research area flows over 43,000 meters across Malang, Indonesia. The research area is divided into the following 5 observation stations. The 1st station located 1250 meter above sea level in Junggo village, Bumiaji District. The 2nd station located 575 meters above sea level in Sengkaling village, Dau District. The 3rd station located 450 meters above sea level in the center of Malang. The 4th station situated approximately 420 meters above sea level in Bumiayu village, Kedung Kandang District. The 5th station located 360 meters above sea level in the downstream area (Figure 1).

b. Class preparation

The course participants were 30 students, divided into five groups. Each group consisted of 6 students with various academic abilities. Each group held a discussion to determine the goal of the project, to look at the logistics for the project implementation, to study the literature on gathering and washing Bacillariophyceae for easier observation. Subsequently, the groups designed the project to observe the Bacillariophyceae in different stations.
2. Creating

a. Field collection of Bacillariophyceae

Students collected the Bacillariophyceae from 5 observation stations located in Brantas River. Each group was responsible for collecting Bacillariophyceae from various observation stations. Students performed such collection for five times by using synthetic substrates made from flat glass. The flat glass with the size of 15 x 10 x 0.5 cm3 was used and exposed for 14 days. Bacillariophyceae was collected by scraping both sides of the glass to be then rinsed off by using 30 ml distilled water. Then, the collected Bacillariophyceae was saved in a sample bottle. Next, five drops of 40% formalin were dropped into the bottle as the preservative. The following processes were performed in the Laboratory of Biology of the Universitas Negeri Malang.

b. Laboratory preparation of Bacillariophyceae

In the laboratory, students rinsed the collected Bacillariophyceae by adding potassium permanganate (KMnO4) until it turned to purple in color and then added by concentrated sulfuric acid (H2SO4) until it turned into clear. Next, the liquid was centrifuged at the speed of 2000 rpm for 10 minutes. The rinse aimed to remove dirt from the frustule so that the specimen would be easy to describe. The supernatant was removed by using a pipette so that it would not contaminate the deposit. After that, the tube was filled with distilled water and centrifuged for one more time. The process was repeated for three times. The deposit was then moved to the sample bottle and 10 ml distilled water was added. Then, such deposit was observed through a light microscope with 400-time zoom. Lastly, the students identified the species of Bacillariophyceae.

3. Processing

a. Sharing: in this stage, students presented the findings of the project, i.e. the Bacillariophyceae species found in each station.

b. Reflection and evaluation: students reflected and evaluated the project-based learning process in groups and individually.

Results and Discussion

1. Species Diversity of Bacillariophyceae Class

![Bacillariophyceae species found in Brantas River](image)

Figure 2. Bacillariophyceae species found in Brantas River
The Bacillariophyceae communities found by five student groups through the project through 5-time collection in each station are presented in Figure 2 and 3 and Table 1

**Table 1. Bacillariophyceae Species found in five observation stations of Brantas River**

<table>
<thead>
<tr>
<th>No</th>
<th>Species</th>
<th>Station</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 2 3 4</td>
</tr>
<tr>
<td>1</td>
<td><em>Achnanthes crenulata</em> Grun.</td>
<td>√ √ -</td>
</tr>
<tr>
<td>2</td>
<td><em>Achnanthes hongarica</em> Grun.</td>
<td>√ √ -</td>
</tr>
<tr>
<td>3</td>
<td><em>Achnanthes lanceolata</em> (Brebb.) Grun.</td>
<td>√ √ -</td>
</tr>
<tr>
<td>4</td>
<td><em>Achnanthes minutissima</em> Kutz.</td>
<td>√ - -</td>
</tr>
<tr>
<td>5</td>
<td><em>Amphora acutiuscula</em> Kutz.</td>
<td>√ √ -</td>
</tr>
<tr>
<td>6</td>
<td><em>Amphora bitumida</em> Prowse.</td>
<td>- √ √ -</td>
</tr>
<tr>
<td>7</td>
<td><em>Amphora bullatoides</em> Hohn &amp; Hellerman</td>
<td>- √ -</td>
</tr>
<tr>
<td>8</td>
<td><em>Amphora delphinea</em> Bailey</td>
<td>√ √ √ √</td>
</tr>
<tr>
<td>9</td>
<td><em>Amphora holsatica</em> Hustedt</td>
<td>- √ -</td>
</tr>
<tr>
<td>10</td>
<td><em>Amphora normannii</em> Robenhurst</td>
<td>- √ -</td>
</tr>
<tr>
<td>11</td>
<td><em>Amphora ovalis</em> Kutz</td>
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</tr>
<tr>
<td>12</td>
<td><em>Amphora proteus</em> Gregory</td>
<td>- √ -</td>
</tr>
<tr>
<td>13</td>
<td><em>Amphora strigosa</em> Hustedt</td>
<td>- √ -</td>
</tr>
<tr>
<td>14</td>
<td><em>Bidulphialeavis</em> Ehr.</td>
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<tr>
<td>15</td>
<td><em>Caloneis bacillum</em> (Grun.) Cleve</td>
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</tr>
<tr>
<td>16</td>
<td><em>Caloneis silicula</em> Ehr.</td>
<td>- √ -</td>
</tr>
<tr>
<td>17</td>
<td><em>Cocconeis pediculus</em> Ehr.</td>
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</tr>
<tr>
<td>18</td>
<td><em>Cocconeis placentula</em> Ehr.</td>
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</tr>
<tr>
<td>19</td>
<td><em>Cocsinodiscus argus</em> Ehr.</td>
<td>√ √ √ -</td>
</tr>
<tr>
<td>20</td>
<td><em>Cymbella kolbe</em> Hustedt.</td>
<td>√ - √ -</td>
</tr>
<tr>
<td>21</td>
<td><em>Cymbella microcephala</em> Grun.</td>
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</tr>
<tr>
<td>22</td>
<td><em>Cymbella tumida</em> (Brebb.) van Heurck.</td>
<td>- √ -</td>
</tr>
<tr>
<td>23</td>
<td><em>Cymbella turgida</em> Gregory</td>
<td>- √ -</td>
</tr>
<tr>
<td>24</td>
<td><em>Cymbella turgidulla</em> Grun.</td>
<td>√ √ -</td>
</tr>
<tr>
<td>Page</td>
<td>Species Name</td>
<td>Status</td>
</tr>
<tr>
<td>------</td>
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</tr>
<tr>
<td>25</td>
<td>Cymbella ventricosa Kutz.</td>
<td>√ √ - - -</td>
</tr>
<tr>
<td>26</td>
<td>Diploneis subovalis Cleve</td>
<td>√ - √ √ -</td>
</tr>
<tr>
<td>27</td>
<td>Eutoniapha Ehr.</td>
<td>√ - √ √ -</td>
</tr>
<tr>
<td>28</td>
<td>Eutonia monodon Ehr.</td>
<td>√ - - √ √</td>
</tr>
<tr>
<td>29</td>
<td>Flagellaria construens (Ehr.) Grun.</td>
<td>√ √ √ - -</td>
</tr>
<tr>
<td>30</td>
<td>Flagellaria crotonensis Kitton</td>
<td>√ √ - √ -</td>
</tr>
<tr>
<td>31</td>
<td>Flagellaria vaucheri Kutz.</td>
<td>√ √ - √ -</td>
</tr>
<tr>
<td>32</td>
<td>Frustulia rhomboide Ehr.</td>
<td>√ √ √ √ -</td>
</tr>
<tr>
<td>33</td>
<td>Frustulia saxonica Rabenhorst</td>
<td>√ √ - √ √</td>
</tr>
<tr>
<td>34</td>
<td>Frustulia vulgaris (Thwaites)</td>
<td>√ √ √ - -</td>
</tr>
<tr>
<td>35</td>
<td>Gomphonema cleveland Fricke</td>
<td>√ √ - √ -</td>
</tr>
<tr>
<td>36</td>
<td>Gomphonema christensen Lowe &amp; Kociolek</td>
<td>√ √ - - √</td>
</tr>
<tr>
<td>37</td>
<td>Gomphonema gracile Ehr.</td>
<td>√ - √ √ √</td>
</tr>
<tr>
<td>38</td>
<td>Gomphonema lanceolatum Ehr.</td>
<td>√ √ - √ √</td>
</tr>
<tr>
<td>39</td>
<td>Gomphonema parvulum Kutz.</td>
<td>√ √ √ √ √</td>
</tr>
<tr>
<td>40</td>
<td>Gomphonema vibrio Ehr.</td>
<td>√ √ - √ √</td>
</tr>
<tr>
<td>41</td>
<td>Gyrosigma scalproides (Rabh.) Cleve</td>
<td>- √ - - √</td>
</tr>
<tr>
<td>42</td>
<td>Gyrosigma spenceri (W. Smith) Cleve</td>
<td>- - - √ √</td>
</tr>
<tr>
<td>43</td>
<td>Hantzchia amphioxys (Ehr.) Grun</td>
<td>√ √ √ - -</td>
</tr>
<tr>
<td>44</td>
<td>Melosira granulata (Ehr.) Rafs.</td>
<td>- √ - √ -</td>
</tr>
<tr>
<td>45</td>
<td>Melosira italika (Ehr.) Kutz</td>
<td>- √ - - -</td>
</tr>
<tr>
<td>46</td>
<td>Melosira solidata Eulenstein</td>
<td>- √ - - -</td>
</tr>
<tr>
<td>47</td>
<td>Melosira varians C. A. Agardh</td>
<td>- √ - √ -</td>
</tr>
<tr>
<td>48</td>
<td>Navicula bacillum Ehr.</td>
<td>√ √ √ √ -</td>
</tr>
<tr>
<td>49</td>
<td>Navicula cineta Grun</td>
<td>- - - √ -</td>
</tr>
<tr>
<td>50</td>
<td>Navicula cryptocephala Kutz</td>
<td>√ √ √ √ -</td>
</tr>
<tr>
<td>51</td>
<td>Navicula cryptotenella Lang, B.</td>
<td>√ √ - √ √</td>
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<tr>
<td>52</td>
<td>Navicula confervacea Kutz</td>
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</tr>
<tr>
<td>53</td>
<td>Navicula cuspidata Kutz.</td>
<td>- - - √ √</td>
</tr>
<tr>
<td>54</td>
<td>Navicula feverborni Hust.</td>
<td>- - √ - -</td>
</tr>
<tr>
<td>55</td>
<td>Navicula pupula Kutz.</td>
<td>√ √ √ √ -</td>
</tr>
<tr>
<td>56</td>
<td>Navicula rhyncocephala Hust.</td>
<td>- √ √ √ √</td>
</tr>
<tr>
<td>57</td>
<td>Neidium iridis (Ehr.) Cleve</td>
<td>- √ - √ √</td>
</tr>
<tr>
<td>58</td>
<td>Nitzschia amphibia Grun.</td>
<td>- √ √ √ √</td>
</tr>
<tr>
<td>59</td>
<td>Nitzschia filiformis (W.Sm.) V.H.</td>
<td>√ - √ √ -</td>
</tr>
<tr>
<td>60</td>
<td>Nitzschia gandersheimiensis Krasski.</td>
<td>√ √ - √ -</td>
</tr>
<tr>
<td>61</td>
<td>Nitzschia gracilis Hantsch</td>
<td>- - - - √</td>
</tr>
<tr>
<td>62</td>
<td>Nitzschia ignorata Krasski.</td>
<td>- - - √ -</td>
</tr>
<tr>
<td>63</td>
<td>Nitzschia microcephala Grun.</td>
<td>- √ - √ √</td>
</tr>
<tr>
<td>64</td>
<td>Nitzschia obtusa W. Smith</td>
<td>- √ - √ √</td>
</tr>
<tr>
<td>65</td>
<td>Nitzschia philippinarum Hust.</td>
<td>√ √ - √ √</td>
</tr>
<tr>
<td>66</td>
<td>Nitzschia palea (Kg.) W. Smith</td>
<td>- √ √ √ √</td>
</tr>
<tr>
<td>67</td>
<td>Nitzschia paradoxa (Gmelin) Grun.</td>
<td>√ √ - - √</td>
</tr>
<tr>
<td>68</td>
<td>Nitzschia ponticula Grun.</td>
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</tr>
<tr>
<td>69</td>
<td>Nitzschia subtilis Hust.</td>
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</tr>
<tr>
<td>70</td>
<td>Nitzschia parvula Lewis</td>
<td>- √ - √ √</td>
</tr>
<tr>
<td>71</td>
<td>Nitzschia sigma (Kulz). W Smith</td>
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</tr>
<tr>
<td>72</td>
<td>Nitzschia stagnorum (Rabh.) Grun.</td>
<td>√ √ - - -</td>
</tr>
<tr>
<td>73</td>
<td>Nitzschia tensis W. Smith</td>
<td>- √ √ √ √</td>
</tr>
<tr>
<td>74</td>
<td>Nitzschia tryblionella Hantsch</td>
<td>√ √ - - √</td>
</tr>
<tr>
<td>75</td>
<td>Pinnularia microstauron (Ehr.) Cleve</td>
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<tr>
<td>76</td>
<td>Surirella angusta Kutz.</td>
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</tr>
<tr>
<td>77</td>
<td>Surirella linearis W. Smith</td>
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</tr>
<tr>
<td>78</td>
<td>Surirella robusta Ehr.</td>
<td>- √ - √ -</td>
</tr>
</tbody>
</table>
Based on Table 1, there were 84 species of Bacillariophyceae found in Brantas River. There were different numbers of varieties and species found in every station. There were 43 species found in the 1st station, 70 species found in the 2nd station, 34 species found in the 3rd station, 53 species found in the 4th station, and 41 species found in the 5th station. The factors contributing to the diversities and different numbers of Bacillariophyceae are still unknown since the course subject only aimed to improve students’ skills in collecting, describing, identifying, and classifying specimen. Such differences possibly resulted from physico-chemical factors, such as flow speed, temperature, dissolved oxygen, BOD, etc. on each different station. It becomes an interesting field of further research.

2. **Taxonomy and descriptions of Class Bacillariophyceae species**

This subsection presents the morphology characteristic descriptions of the species found in the five observation stations of Brantas River. The identification of each species was made based on the references which explained about each species written after the names in taxonomy. The followings are several abbreviations related to taxonomic descriptions.

<table>
<thead>
<tr>
<th>No.</th>
<th>Species Name</th>
<th>L (µm)</th>
<th>W (µm)</th>
<th>D (µm)</th>
<th>S (10 µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>79</td>
<td><em>Surirella tenuisima</em> Hust</td>
<td>-</td>
<td>√</td>
<td>√</td>
<td>-</td>
</tr>
<tr>
<td>80</td>
<td><em>Stauroneis anceps</em> Ehr.</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>-</td>
</tr>
<tr>
<td>81</td>
<td><em>Stauroneis phonicenteron</em> (Nitz ) Ehr</td>
<td>-</td>
<td>√</td>
<td>√</td>
<td>-</td>
</tr>
<tr>
<td>82</td>
<td><em>Stauroneis pusila</em> A. Cleve</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>-</td>
</tr>
<tr>
<td>83</td>
<td><em>Synedra rampens</em> Kutz.</td>
<td>-</td>
<td>-</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>84</td>
<td><em>Synedra ulna</em> (Nitz.) Ehr</td>
<td>-</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>43</strong></td>
<td><strong>70</strong></td>
<td><strong>34</strong></td>
<td><strong>53</strong></td>
</tr>
</tbody>
</table>

L: shell length  
W: shell width  
D: shell diameter  
S: striae number in 10 µm  
P: punctae in 10 µm  

Ordo: Centrales  
Sub Ordo: Coscinoidiceneae  
Family: Coscinodiscaceae  
Genus: Coscinodiscus  
1. *Coscinodiscus argus* Ehr\(^{24}\).  
   D. 70-100 µm  
Genus: Melosira  
2. *Melosira granulata* (Ehr.) Ralfs. \(^{24,26}\).  
   L. 16-28 µm, D. 5-10; S. 8-11 in 10 µm  
3. *Melosira italika* (Ehr.) Kutz. \(^{24,25,29}\).  
   L. 16-28 µm, D. -10 µm, S 10-20 in 10 µm  
4. *Melosira solida* Eulenstein\(^{25,27}\).  
   D. 9 µm,  
5. *Melosira varians* C. A. Agardh\(^{28}\).  
   L. 13-16 µm, D. 8-35 µm  

Sub Ordo: Biddulphineae  
Family: Biddulphiaceae  
Genus: Fragilaria  
6. *Bidulphialeavis* Ehr. \(^{24}\).  
   D. 65-120 µm  
Order: Pennales  
Sub Order: Araphidinneae  
Family: Fragillariaceae  
Genus: Fragilagina  
7. *Fragilaria construens* (Ehr.) Grun\(^{26,29}\).
8. *Fragilaria crotonensis* Kitton\(^{25,27,29}\)  
   L. 40-170, W. 2-4(5) \(\mu\)m, S. 11-15 in 10 \(\mu\)m

9. *Fragilaria vaucherasia* Kutz.\(^{24,25}\)  
   L. 50-90 \(\mu\)m, W. 3-6 \(\mu\)m, S. 9-12 in 10 \(\mu\)m

Genus: *Synedra*  
10. *Synedra rumpens* Kutz.\(^{25,28}\)  
   L. 40-170, W. 2-4(5) \(\mu\)m, S. 11-15 in 10 \(\mu\)m

11. *Synedra ulna* (Nitz.) Ehr.\(^{24,25,27,28}\)  
   L. 150-250 \(\mu\)m, W. 5-7 \(\mu\)m, S. 8-10 in 10 \(\mu\)m

Sub Order: Raphidiodineae  
Famili: Eunotiaceae  
Genus: *Eunotia*  
12. *Eutonia faba* Ehr.\(^{24}\)  
   L. 13-15 \(\mu\)m, W. 3-4 \(\mu\)m, S. 19-20 in 10 \(\mu\)m

13. *Eutonia monodon* Ehr.\(^{28}\)  
   L. 65-70 \(\mu\)m, W. 10-15 \(\mu\)m, S. 10-12 in 10 \(\mu\)m

Sub Order: Monoraphidinae  
Family: Achnantaceae  
Genus: *Achnanthes*  
14. *Achnanthes crenulata* Grun.\(^{30}\)  
   L. 30-87 \(\mu\)m, W. 13-22 \(\mu\)m, S. 8-9 in 10 \(\mu\)m

15. *Achnanthes hongarica* Grun.\(^{23}\)  
   L. 16-18 \(\mu\)m, W. 4.5-7.5 \(\mu\)m, S. 18-24 in 10 \(\mu\)m

16. *Achnanthes lanceolata* (Breb) Grun.\(^{23}\)  
   L. 12-31 \(\mu\)m, W. 4.5-8 \(\mu\)m, S. 11-14 in 10 \(\mu\)m.

17. *Achnanthes minutisima* Kutz.\(^{27}\)  
   L. 5-25 \(\mu\)m, W. 2.5-4 \(\mu\)m (mostly 3-3.5 \(\mu\)m), S. 30-32 in 10 \(\mu\)m.

Genus: *Cocconeis*  
18. *Cocconeis pediculus* Ehr.\(^{25,27,29}\)  
   L. 5-25 \(\mu\)m, W. 8-40 \(\mu\)m, S. 27-32 in 10 \(\mu\)m

19. *Cocconeis placentula* Ehr.\(^{25,29}\)  
   L. 7.5-98 \(\mu\)m, W. 8-40 \(\mu\)m, S. 24-26 in 10 \(\mu\)m

Sub Order: Biraphidineae  
Family: Naviculaceae  
Genus: *Caloneis*  
20. *Caloneis bacillum* (Grun.) Cleve\(^{25,27,29}\)  
   L. 15-40 \(\mu\)m, W. 4-9 \(\mu\)m, S. 22-28 in 10 \(\mu\)m

21. *Caloneis silicula* Ehr.\(^{23,29}\)  
   L. 25-120 \(\mu\)m, W. 6-24 \(\mu\)m, S. 16-20 in 10 \(\mu\)m

Genus: *Diploneis*  
22. *Diploneis ovalis* Cleve\(^{24}\)  
   L. 20-25 \(\mu\)m, W. 12-15 \(\mu\)m, P. 18-22 in 10 \(\mu\)m

Genus: *Frustulia*  
23. *Frustulia rhomboides* Ehr.\(^{24,29}\)  
   L. 30-55 \(\mu\)m, W. 8-12,5 \(\mu\)m, S. 30-35 in 10 \(\mu\)m

24. *Frustulia saxonica* Rabenhorst.\(^{24,29}\)  
   L. 30-40 \(\mu\)m, W. 8-10 \(\mu\)m, S. 29-32 in 10 \(\mu\)m

25. *Frustulia vulgaris* (Thwaites)\(^{25,29}\)  
   L. 40-60 \(\mu\)m, W. 8-12 \(\mu\)m, S. 27-32 in 10 \(\mu\)m

Genus: *Gyrosigma*  
26. *Gyrosigma scalploides* (Rab.Cleve Hust)  
   L. 40-70 \(\mu\)m, W. 7-11 \(\mu\)m, S. 20-24 in 10 \(\mu\)m

27. *Gyrosigma spenceri* (W. Smith) Cleve.\(^{27}\)
Genus: *Navicula*

28. *Navicula bacillum* Ehr.\(^\text{25}\)  
   L. 30-80 μm, W. 10-20 μm, S. 12-14 in 10 μm

29. *Navicula cincta* Grun(Ehrenberg) Ralfs\(^\text{29}\)  
   L. 14-45 μm, W. 5.5-8 μm, S. 8-12 in 10 μm

30. *Navicula cryptocephala* Kutz\(^\text{25,27,29}\)  
   L. 24-42 μm, W. 5-7 μm, S. 15-16 in 10 μm

31. *Navicula cryptotenella* Lang, B.\(^\text{25,27,29}\)  
   L. 12-40 μm, W. 5-7 μm, S. 14-16 in 10 μm

32. *Navicula confervacea* Kutz\(^\text{24,25,27,29}\)  
   L. 18-25 μm, W. 7-9 μm, S. 18-20 in 10 μm

33. *Navicula cuspidata* Kutz.\(^\text{23,24,29}\)  
   L. 95-100 μm, W. 25-30 μm, S. 17-18 in 10 μm

34. *Navicula feverbornii* Hust.\(^\text{23,24}\)  
   L. 40-48 μm, W. 6-8 μm, S. 10-12 in 10 μm.

35. *Navicula pupula* Kutz.\(^\text{23,25,27}\)  
   L.10-90 μm, W. 13-15μm ; S.18-19 in 10 μm.

36. *Navicula rhyncocephala* Hust.\(^\text{25,27}\)  
   L. 27-30 μm; W. 8,5-10 μm; S. 10-12 in 10 μm.

Genus: *Neidium*

37. *Neidium iridis* (Ehr.) Cleve.\(^\text{23,24}\)  
   L. 35-40 μm, W. 10-20 μm, S. 16-18 μm

Genus: *Pinnularia*

38. *Pinnularia microstauron* (Ehr.)\(^\text{24,28}\)  
   L.50-70μm, W. 10-14μm, S. 10-13 in 10μm

Genus: *Stauroneis*

39. *Stauroneis anceps* Ehr.\(^\text{23}\)  
   L. 47-48μm , W. 11-12 μm, S. 16-18 in 10 μm .

40. *Stauroneis phonicenteron* (Nitz) Ehr.\(^\text{23,28}\)  
   L. 49-56 μm, W.7-11 μm, S. 12-20 in 10 μm

41. *Stauroneis pusila* A. Cleve\(^\text{24}\)  
   L. 30-45 μm, W. 7-11 μm, S. 30 in 10 μm

Genus: *Gomphonema*

42. *Gomphonema clevei* Fricke.\(^\text{25,28}\)  
   L. 12-50 μm, W. 4-9 μm, S. 10-18 in 10 μm

43. *Gomphonema christensenii* Lowe & Kociolek\(^\text{25}\)  
   L.46-73 μm, W. 8,5-10 μm, S. 11-13,5 in 10 μm

44. *Gomphonema gracile* Ehr.\(^\text{23,24}\)  
   L. 40-50 μm , W. 8-10 μm, S.12-15 in 10 μm

45. *Gomphonema lanceolatum* Ehr.\(^\text{24}\)  
   L. 20-70 μm, W. 7-10 μm, S. 8-10 in 10 μm

46. *Gomphonema parvulum* Kutz\(^\text{25,26,29}\)  
   L. 10-36 μm, W. 4-8 μm, S. 7-20 in10 μm

47. *Gomphonema vibrio* Ehr.\(^\text{25,26}\)  
   L. 20-37 μm, W. 4-5 μm, S. 10-14 in 10 μm

Family: Cymbellaceae

Genus: *Amphora*

48. *Amphora acutiuscula* Kutz\(^\text{24,29}\)  
   L. 30-60 μm, W. 6-8 μm, S. 18-20 in 10 μm.

49. *Amphora bitumida* Prowse.\(^\text{24}\)  
   L. 18-23 μm, W. 11-12 μm, S. 17-18 in 10 μm

50. *Amphora bullaoides* Hohn & Hellerman\(^\text{31}\)  
   L. 17-30 μm, W. 4-6 μm, S. 16-18 in 10 μm

51. *Amphora delphinea* Bailey\(^\text{23}\)
52. *Amphora holsatica* Hustedt. 24
   L. 40-45 μm, W. 7-9 μm, S. 12-13 in 10 μm
53. *Amphora normannii* Robenhourst. 24
   L. 30-40 μm, W. 9-14 μm, S. 16-20 in 10 μm
54. *Amphora ovalis* Kutz. 23,25,27
   L. 32-95 μm, W. 8-10 μm, S. 17 in 10 μm
55. *Amphora proteus* Gregory. 24
   L. 40-60 μm, W. 7-10, S. 10-13 in 10 μm
56. *Amphora strangosa* Hustedt. 24,29,29
   L. 17-70 μm, W. 3,5-6,2 μm, S. 16-20 in 10 μm

Genus: *Cymbella*
57. *Cymbella kolbei* Hustedt 24,29
   L. 25-30 μm, W. 9-11 μm, S. 11-12 in 10 μm
58. *Cymbella microcephala* Grun 27,29
   L. 10-23 μm, W. 3,5-4,2 μm, S. 23-25 in 10 μm
59. *Cymbella tumida* (Breb.) van Heurck 25,27,29
   L. 35-95 μm, W. 16-24 μm, S. 8-13 in 10 μm
60. *Cymbella turigida* Gregory
   L. 31-52 μm, W. 10-14 μm, S. 11-12 in 10 μm
61. *Cymbella turigidula* Grun 23,25,29
   L. 30-50 μm, W. 11-14 μm, S. 8-14 in 10 μm
62. *Cymbella ventricosa* Kutz. 24,29
   L. 21-29 μm, W. 5-7 μm, S. 14-19 in 10 μm

Family: *Nitzchiaceae*
Genus: *Hantzchia*
63. *Hantzchia amphioxys* (Ehr.) Grun 26,29
   L. 30-100 μm, W. 5-10 μm, S. 13-20 in 10 μm

Genus: *Nitzchia*
64. *Nitzchia amphibia* Grun 25,27,28
   L. 18-20 μm, W. 4,6-5,0 μm, S. 16-17 in 10 μm.
65. *Nitzchia filiformis* (W. Sm.) V. H. 25,27
   L. 40-100 μm, W. 4-6 μm, S. 27-36 in 10 μm
66. *Nitzchia gandersheimiensis* Krasski. 24,27
   L. 90-100, W. 4 μm, S. >30 in 10 μm
67. *Nitzchia gracilis* Hantzsch 27,28
   L. 45-110 μm, W. 2,5-4 μm, S. 38-42 in 10 μm
68. *Nitzchia ignorata* Krasski. 24
   L. 40-60 μm, W. 4 μm, S. >30 in 10 μm
69. *Nitzchia microcephala* Grun. 24
   L. 10-19 μm, W. 2,3-4 μm, S. 30-41 in 10 2,3-4 μm
70. *Nitzchia obtusa* W. Smith. 24,25,27
   L. 25-80 μm, W. 4-5 μm, S. 28-30 in 10 μm
71. *Nitzchia philipinarum* Hust 28
   L. 65-70 μm, W. 3,5-4,5 μm, S. 32 in 10 μm
72. *Nitzchia palea* (Kg.) W. Smith. 23,25,27,28
   L. 15-70 μm, W. 2,5-5 μm, S. 28-40 in 10 μm.
73. *Nitzchia paradoxa* (Gmelin) Grun. 24
   L. 60-90 μm, W. 5-8 μm, S. 20-24 in 10 μm
74. *Nitzchia ponticula* Grun. 24
   L. 12-15 μm, W. 2,4 μm, S. 28-30 in 10 μm
75. *Nitzchia subtilis* Hust. 24
   L. 90-130 μm, W. 3-5 μm, S. 28-32 in 10 μm
76. *Nitzchia parvula* Lewis. 24
   L. 30-40, W. 4-5 μm, S. 29-30 in 10 μm.
77. *Nitzchia sigma* (Kulz). W Smith 24
L. 35-100 µm, W. 4-5 µm, S. 22-30 in 10 µm
78. Nitzschia stagnorum (Rabh.) Grun.24
L. 30-60 µm, W. 6-10 µm, S. 26 in 10 µm
79. Nitzschia tenuis W. Smith27
L. 146 µm, W. 5 µm, S. 25 in 10 µm
80. Nitzschia tryblionella23,27
L. 60-180 µm, W. 16-35 µm, S. 30-35 in 10 µm

Family: Surilellaceae
Genus: Surirella
81. Surirella angusta Kutz.27
L. 30-50 µm, W. 9-10 µm, S. 22-28 in 10 µm
82. Surirella linearis W. Smith24,28
L. 40-100 µm, W. 12-20 µm, S. 23 in 10 µm
83. Surirella robusta Ehr.23
L. 48-72 µm, W. 28-34 µm, S. 44-60 in 10 µm
84. Surirella tenuisima Hust
L. 17-38 µm, W. 6-11 µm

The Bacillariophyceae communities in Brantas River found by the students were then classified based on the genera, families, sub orders and orders. From such classification, they found 22 genera, 10 families, six sub orders and two orders, namely Pennales and Centrales. The main diversities between the order Pennales and Centrales are valve structures and ornamentation. The Centrales valve is round, ellipse, polygonal and irregular between radial or concentric ornamentations, while the Pennales valve is an ellipse with bilateral symmetrical ornamentation.4,33-34

The Pennales order presents various valve areas. There is a gap called raphe found across the entire or a part of thecell wall in Pennales order. There are also Pennales members with rudimentary raphe located on the edge of the cell wall creating pseudoraphe.5 According to the structures, Pennales order consists of four sub orders.5 The first is Araphidineae which have a pseudoraphe, such as Asterionella, Diatom, Fragilaria, and Synedra. The second is Raphidiodineae which have rudimentary rapheat the edges of thecell, for example Actinella and Eutonia. The third is Monoraphidinaceae which have a raphe in one valve and a pseudoraphe in another valve, such as Achnanthas and Cocconeis. The last is Biraphidineae which have raphes on both valves, e.g. Amphora, Cymbella, Gomphonema, Navicula, Nitzschia, Pinnularia and Surirella.

There is not a raphe in the Centrales order valves. The frustules of centrales order are discoid, cylindrical or irregular.4,24. The Centrales Order includes three sub orders.6,7. The first is Coscinodiscaceae with the cylindrical cell, round valves, radial striae structures such as Cyclotella and Melosira. The second is Rhizosoleniaceae with elongated, cylindrical or sub cylindrical cell, a complex girdle with several bands such as Rhizosolenia. The third is Biddulphiaceae with the square cell, two or more popping valves like animal horns, such as Biddulphia and Triceratium.

The most abundant Bacillariophyceae communities in Brantas River were from the order Pennales of 79 species (94%) while there were only five species (6%) identified from order Centrales. The order Pennales were dominantly identified in freshwater since it is its typical environmental niche and they live as periphyton.29 Many Pennales were found attaching to the flat glass since they are more adhesive than the species included in the order Centrales. The order Pennales has crystalloid organelle and fibrils which produce mucous (mucilage) or chitin organelle to attach, such as the genus Cocconeis, Achnanthas, and Synedra.37 Such organelles are not found in the orders of Centrales. Therefore, most of Centrales are planktonic24,29,38. Some species from the genus Cyclotella and genus Melosiralive as periphyton temporarily.

In this research, the students could identify the Bacillariophyceae specimens found in each station collaboratively in groups. In performing the project, students did brainstorming, respected others’ opinions, and worked in a team to produce ideas. They negotiated to solve problems collectively and finally did self-evaluation. The project-based learning seems promotes social skills such as negotiating, communicating, collaborating, being creative, and problem solving.15,39
Each group has determined the purpose of the project and designed a real scientific investigation to implement the project. The project-based learning can improve the students’ ability to conduct research. There are several essential aspects of project-based instruction for the success of projects, namely, among others, the harmony between the learning purpose and the implemented project and real-world investigation skill. The collection of Bacillariophyceae was followed by the process of description and identification in a fragment of Brantas River related to the real daily lives of the students. The projects have to relate to the real world situation. Thus, students can understand what they learn and why they learn it.

Conclusion

The project-based learning method utilized in Thallophyta course subject has given students the opportunity to get experiences in collecting, describing, identifying, and clarifying the Bacillariophyceae they found from Brantas River. They found 43 species in the 1st station, 70 species in the 2nd station, 34 species in the 3rd station, 53 species in the 4th station, and 41 species in the 5th station. The different number of species found at each stations seems interesting for further research to find out the reason that contribute to those factors.

References


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